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RESIDENTIAL WOOD FUEL USE ASSESSMENT

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RESIDENTIAL WOOD FUEL USE ASSESSMENT

Prepared by

ECO Northwest, Ltd.
1400 Eleventh Avenue
Helena, Montana 59601

September 1984

Prepared for

Montana Department of Natural Resources and Conservation
1520 East 6th Avenue, Helena, Montana 59620
Planning and Analysis Bureau
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ERRATA

Algorithm #14 found in Section D, Chapter IV, should be expressed as :

$$SATW_t = (SATW + (C * AFSC_t))$$

This specification eliminates the GAMMA time response factor discussed in Chapter IV. Elimination of this term increases wood saturation by approximately one percent over the entire forecast period. Although the effect of this change on the projection is insignificant, the above specification is more defensible than the original algorithm.

ABSTRACT

This analysis represents a continuation of wood use analysis and forecasting conducted primarily by Norman Marshall and the U.S. Department of Energy. The emphasis of the research effort was to explore alternative wood use forecasting and estimation procedures.

The analysis focuses on estimating historical wood use patterns in Montana and determining causal factors influencing such change. Survey analysis, econometric techniques, and simulation procedures are utilized to assist in quantitatively defining future residential energy wood use levels in Montana. The simulation model is available from the Montana Department of Natural Resources and Conservation for Apple IIs and IBM PCs.

I. INTRODUCTION

A. Objectives

The public image of wood as a fuel, once perceived to be both an inexpensive and renewable energy resource, has now become somewhat tarnished. In the Missoula and Helena areas, for example, air quality degradation resulting from a high concentration of often poorly operated wood stoves and a natural tendency toward air inversions, has become an issue of public concern. On the national level, the Environmental Protection Agency will decide by year end whether to attempt to regulate wood stoves.

Through primary funding from the U.S. Department of Energy (DOE), the Montana Department of Natural Resources and Conservation (DNRC) contracted with ECO Northwest, Ltd. (ECO) to study residential wood fuel use within Montana. The purposes of this investigation were: 1) to attempt to define the influences on residential wood fuel use within Montana, and 2) to provide a plausible projection for future wood fuel use with emphasis on the Montana Power Company's (MPC) electrical service area. The fundamental question of interest was: to what extent will wood contribute to Montana's future residential energy needs? A secondary question was concerned with the degree that probable rises in electrical rates will contribute to increased wood fuel consumption.

B. Difficulties in Analyzing Wood Use

> Everyone knows that woodburners save money when they stoke their fires and shut off the utilities. Aside from the warm pleasures of snuggling up to a toasty woodstove, and the satisfaction of sticking it to the power company, favorable economics are the major justification for those who burn wood seriously.[1]

The primary difficulty in analyzing the economics of wood heat is that of assigning a cost to the wood itself. Conventional wisdom holds that money can be saved by turning off the furnace and firing up the stove; however, this cannot be easily proven because there are no accurate data on the costs of either purchased or self-cut wood. While the cost of purchased wood appears to be approximately $60 per cord (80 cubic feet or 2,500 dry weight pounds), it is difficult to determine how individual woodcutters account for the cost of wood. The range of possible costs is extremely wide. At the very minimum, the price of gasoline used in cutting and hauling (25 miles one-way) would be approximately $6.00 per cord. If the full cost of equipment (pickup at $.30/mile and a $200 chainsaw over 10 years) were embodied in the estimate, costs for the average woodburner could rise by an additional $20.00 per cord. These costs, however, do not include either the value of time required to cut, haul, and split the wood, or to tend a fire which have been estimated at 8 hours and 11 hours per cord, respectively.[2,3] Other sources estimate the average time required

---

[1] Peter Neilson, "The Economics of Woodburning in Missoula, Montana," no date, unpublished paper, University of Montana, Environmental Studies Program.

[2] U.S. Department of Energy, "Heating with Wood," DOE/CS-0158, May 1980, p.6.

[3] Ted Williams, "When Does It Pay to Burn Wood?", Organic Living (September 1982), p.82.

to produce and burn one cord of wood to be 26.5 hours.[4] If the time (8 hours per cord) spent cutting, hauling, and splitting firewood were valued at, for example, $4.50 per hour (more or less 50 percent average wage rate), the total user cost of wood (excluding the stove itself, installation, operation, maintenance or repair) would rival the current purchase price of $60 per cord. Actual out-of-pocket costs, however, would only be $6.00 per cord, or just over 10 percent of the current purchase cost of wood.

If three cords of wood (19 million BTUs per cord) were burned in a stove costing $1,250 (amortized at 11 percent over 10 years, 60 percent efficiency, $75 annual maintenance/repair cost), the total cost per million BTU (including fuel) could conceivably range between $3.00 and $18.00, depending upon how the consumer perceived their costs (i.e., actual out-of-pocket costs only treating the stove installation as a sunk cost, or fully amortized cost including the value of time). If all costs were considered with the exception of time itself, the costs of wood heat are estimated to be approximately $10.50 in this example versus electrical costs of $14.50 per million BTU (assuming $750 electrical capacity costs, 11 interest percent over 20 years, and 40 mill power). Although the actual costs of wood energy are dependent on the price of purchased wood or the costs associated with self-cut wood, stove efficiency, operational practices, and so forth, the example does reveal the wide range of costs that woodburners could perceive to be true. Perceptions of cost savings may be a more important influence on wood use than actual cost savings.

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[4] David E. White and George E. Wilson, "The Cost of Heating With Wood," West Virginia University, Cooperative Extension Service, no date, p.680 EG 10.1.10.

This perception of cost savings greatly complicates forecasting wood use.

The forecasting problem is further complicated by lack of data. Although some survey data exist for Montana, such as city-specific or one-time state surveys, there is no completely reliable historical time series for wood use, and fundamentally no price data available. As a result, traditional econometric or end use procedures are of limited value in forecasting or sometimes, even for analyzing what factors influenced the recent growth in wood use.

The "amenity value" of the product itself also presents a problem in analyzing wood use. Specifically, the heat provided by a wood stove is considered by many wood stove owners to be superior to gas and electric heat. The ability to stand next to a stove after coming indoors from a cold winter day and warming up immediately places wood in a somewhat different category than conventional heating systems. Similarily, the aesthetic and recreational value of wood, as well as the household inconvenience costs of wood, make economic comparisons with gas and electric heat extremely difficult.

C. Organization

Chapter II of this report reviews wood data sources and provides a brief review of relevant literature. Specific attention is focused on those variables that appear to influence wood consumption.

Chapter III reports the findings of a recent statewide general public survey. This survey was designed to determine woodburner/nonwoodburner attitudes toward wood consumption, wood costs, pollution, and inconvenience.

Chapter IV discusses the development of a wood use simulation system designed to project consumption under a variety of price, conservation, and household formation scenarios. The sensitivity of the model to various parameter values is also explored.

Chapter V provides a range of "plausible" forecasts through 1995 and a discussion of the subjective probability of each projection. Potential improvements or refinements to the model are also outlined.

II. WOOD CONSUMPTION PATTERNS

A. Growth in Wood Consumption

There are a variety of sources of information on wood use within Montana and throughout the nation. While no one source of data tells the whole story, collectively the sources reveal an unmistakable pattern--wood use is on the rise.

Figure 1 depicts wood energy consumption from 1850 to 1980. In 1850, more wood was utilized for energy than for any other purpose,[5] and in the 1870s, wood energy consumption peaked at nearly three quadrillion BTUs (quads) per year. From 1880 to 1960, wood consumption gradually declined; however, in 1960, when wood consumption was at the lowest point, wood energy use slowly started to increase. This increase was due to the forest products industry growth (and, therefore, the generation of more wood wastes) and environmental restrictions on open burning and landfill disposal of industrial wood residues.[6]

Since 1974, rapidly rising energy costs have stimulated the utilization of wood energy significantly. Residential space heating has shown the greatest percentage gain even though the greatest absolute increase has occurred within the forest products industry. Although it can be reported that the most common form of home heating wood fuel is cut-and-split stick wood, estimating the current consumption is difficult because residential wood fuel use is very dispersed and much of the fuel is acquired and used outside the reported economy.

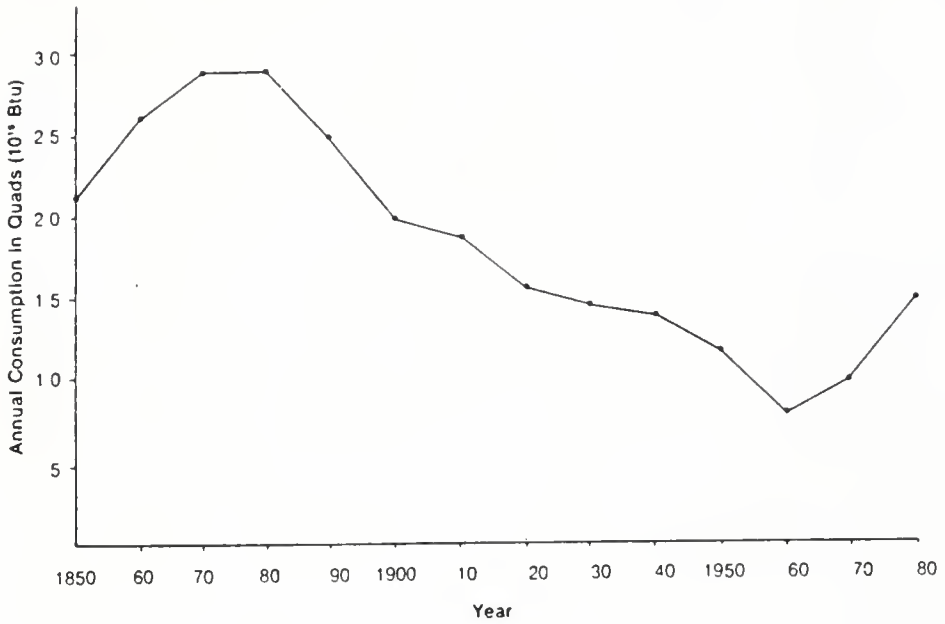
---

[5] M. Clawson, "Forests in the Long Sweep of American History," Science (1979), 204:1168-74.

[6] D. Tillman, Wood as an Energy Resource (New York: Academic, 1978), 247 pp.

FIGURE 1

NATIONAL WOOD ENERGY CONSUMPTION - ALL USES



Source: Charles E. Hewett et. al., "Wood Energy in the United States," Ann. Rev. Energy (1981), 6:139-70.

Although state and local area surveys of wood use are the most common method of estimating residential consumption, several regional and national surveys have also been conducted. A variety of Montana surveys exist (see Table 1), but with the exception of the two Missoula surveys, little can be definitely said about the rate at which wood use has increased. The two Missoula surveys suggest that both the saturation rate and wood use per household were up significantly over a comparatively short period of time (1977-80). Nevertheless, two state level surveys as well as an MPC survey, suggest that wood use on a household basis "may" have been stable for the past few years. Comparisons of surveys utilizing different sampling techniques and different questions, however, is not without risk. And, as a general rule, survey data, unless gathered on a systematic and recurring basis, is of limited value in terms of establishing an annual wood use series.

To alleviate the problem of a lack of consistent state level time series, the DOE contracted Applied Management Sciences to conduct a comprehensive wood use study in 1982. Their report provides estimates on a state-by-state basis over the 1960-81 period and are, for the most part, derived from national wood stove shipment data, census saturation data, and state heating degree day estimates.[7] Although the estimates (see Figure 2) have been criticized because of the number of assumptions involved, the time series data appear to be reasonable in view of other point estimates and changes in energy prices.

---

[7] Applied Management Sciences, "Estimates of U.S. Wood Energy Consumption from 1949 to 1981," 1982, prepared for U.S. Department of Energy.

TABLE 1

CITY AND STATE
SATURATION RATES AND WOOD USE

Area	Year	Primary and Secondary Heat Percent of Total Homes	Wood Use Cords Per Year Per Household With Wood Heat
Helena	1980-81[1]	34%	2.1
Bozeman	1980-81[1]	32%	2.3
Great Falls	1980-81[1]	27%	2.5
Kalispell	1980-81[1]	40%	3.2
Missoula	1976-77[2]	38%	1.9
Missoula	1979-80[2]	53%	2.7
State of Montana	1984[3]	47%	2.6
State of Montana	1979-80[4]	45%	2.7
MPC Service Area	1982[5]	51%	N/A
North Rocky Mountains (Idaho, Montana, Wyoming)	1980-81[6]	N/A	2.5

Sources:

[1] Western Montana Scientists' Committee for Public Information, "Survey of Residential Wood Use in Helena, Bozeman, Great Falls, and Kalispell, Montana," 1981, prepared for the Montana Department of Health and Environmental Sciences, Air Quality Bureau.

[2] Scott Church (principal researcher), "Residential Wood Burning and Its Impact on Particulate and Carbon Monoxide Emissions in the Missoula Urban Area 1979-80," 1980, prepared for the Missoula County Health Department.

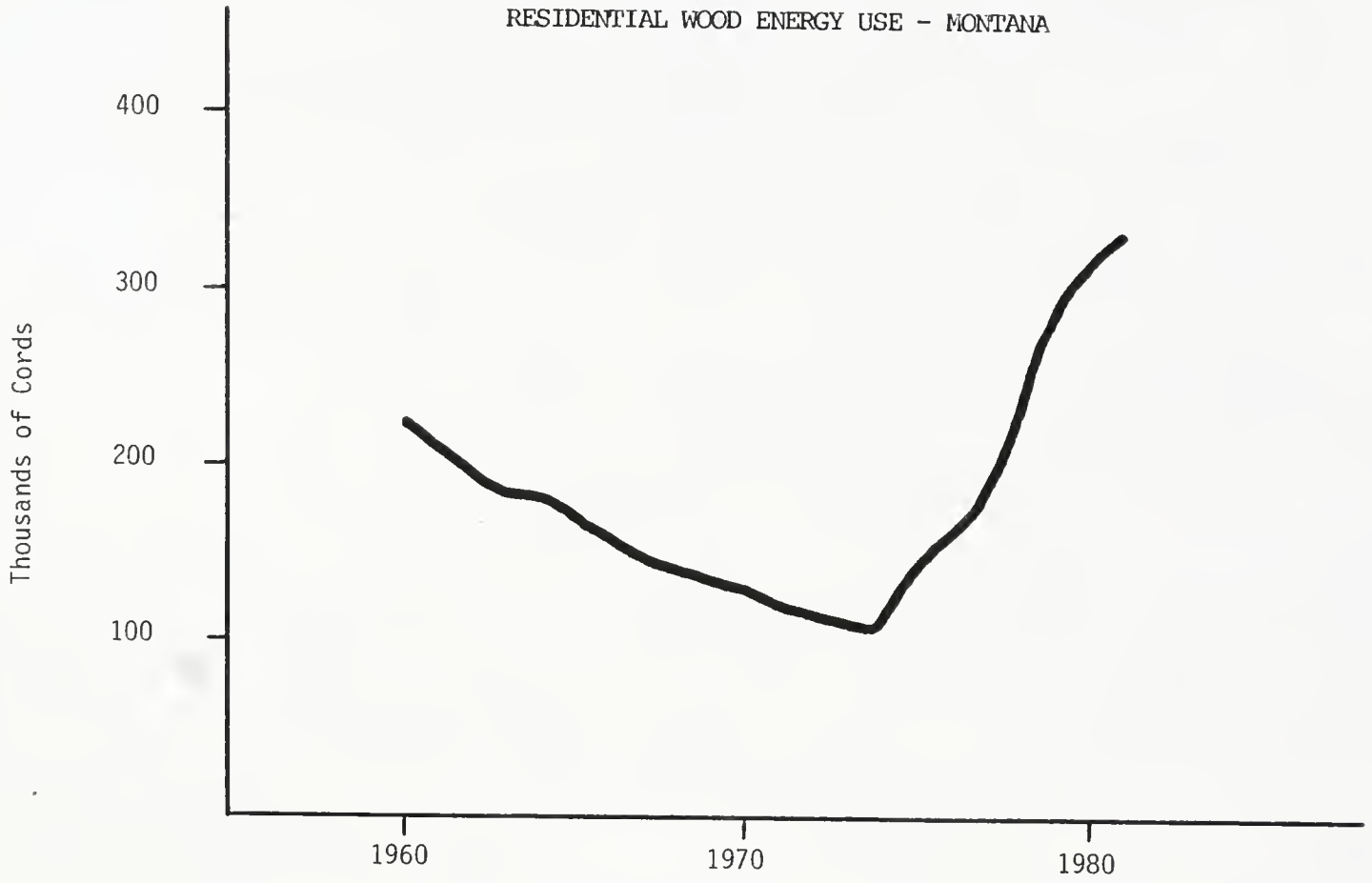
[3] ECO Northwest, Helena, Montana, Wood fuel use telephone survey, 1984, conducted for Montana Department of Natural Resources and Conservation, Energy Division. This estimate is based on the response to Q-23 of the general public survey (Appendix A) and assumes the midpoints of the interval responses. The upper interval assumes 7.5 cords per year.

[4] Elrick & Lavidge, Inc., "The Pacific Northwest Residential Energy Survey," 1980, prepared for the Bonneville Power Administration and Pacific Northwest Utilities Conference Committee.

[5] Montana Power Company, Butte, Montana, "1982 Residential Survey, Executive Summary," 1982.

[6] K. Skog, "Survey Confirms Sharp Increase in Home Woodburning," no date, Forest Product Laboratory, U.S. Forest Service, U.S. Department of Agriculture.

FIGURE 2



Source: Applied Management Sciences "Estimates of U.S. Wood Energy Consumption from 1949 to 1981," 1982, prepared for U.S. Department of Energy.

Table 2 provides a comparison of estimates of residential wood consumption in Montana. These estimates exhibit considerable variation, perhaps the result of using different methods, and in the case of the ECO estimate, a different time period. The DOE estimate was a simple conversion of published tonnage estimates to cords (assuming a 2,500 pound dry weight cord). The U.S. Forest Service (USFS) estimate was based on the the number of sold and free use permits issued by the Montana national forests and the number of cords allowed for each permit. The USFS estimate, originally expressed in thousands of board feet, was converted to cords (assuming 2.5 pounds per board feet and a 2,500 pound dry weight cord). Although the USFS estimate is the lowest of the 1980 values, the increase in this annual series over the last five years of existing data (1977-82) is approximately 200 percent increase versus a 117 percent increase over the last five years of the DOE series (1976-81). The Elrick and Lavidge estimate, based on a statewide survey, was derived from the 1980 surveyed saturation rate for primary and secondary wood fuel use, the 1980 number of households (1980 census), and the Elrick and Lavidge estimate of wood use per household with woodburners. The ECO estimate was based on the same technique; that is, current households (1984 estimate 310,000) times the saturation rate (47 percent) times average wood use per household with wood heat (2.6 cords).

In all probability, the Elrick and Lavidge and ECO survey estimates are more reliable than those of either the DOE or USFS. There is, however, likely to be substantial error in the surveys resulting from the rather nebulous nature of definition of a cord of wood itself. Nevertheless, in spite of this uncertainty, it is apparent from all sources in a collective sense, that wood fuel use sharply increased during the 1970s and early 1980s.

TABLE 2

MONTANA RESIDENTIAL WOOD CONSUMPTION

	Source	1,000s of Cords
1)	Department of Energy (1980)	302.4
2)	U.S. Forest Service (1980)	188.4
3)	Elrick & Lavidge (BPA-1980)	264.0
4)	ECO Northwest, Ltd. (1984)	379.2

Sources:

1) Derived from Applied Management Sciences, "Estimates of U.S. Wood Energy Consumption from 1949 to 1981," 1982, prepared for U.S. Department of Energy.

2) Derived from unpublished Firewood Analysis Data, 1983, Region 1, U.S. Forest Service, Missoula, Montana.

3) Derived from Elrick & Lavidge, Inc., 1980, "The Pacific Northwest Residential Energy Survey," prepared for the Bonneville Power Administration and Pacific Northwest Utilities Conference Committee.

4) ECO Northwest, Ltd., wood fuel use telephone survey, 1984, conducted for the Montana Department of Natural Resources and Conservation, 1984.

B. Factors Influencing Wood Use

Assuming the DOE estimates (see Figure 2) are accurate, total residential wood fuel use in Montana steadily declined between 1960 and 1974. Over this period, the real (inflation adjusted) price of natural gas was relatively constant and the real price of electricity was steadily falling. Between 1974 and 1981, however, the real price of gas more than doubled, leading to a resurgence in residential wood fuel consumption.

ECO's analysis of the DOE data, competing energy prices (gas, electricity, and oil), household formation rates, and urban/rural growth patterns suggest the following general conclusions:

1) The rise in residential wood use was primarily related to the rapid increase in natural gas prices during the mid-to-late 1970s. Comparable increases in fuel oil and LP prices probably also contributed to higher wood use levels.

2) During the period 1970-80, the number of households in Montana grew from 217,304 to 283,742--a thirty percent increase.

3) Sixty percent of the household growth in Montana occurred outside the city limits where gas heat was often not available. As a result, there was a dramatic increase in electrical space heat saturation. The shift from liquid fuels to electric space heat was also reinforced by declining real electrical prices. Many of these new homes had wood back-up heat. These changes in saturation rates are shown in Table 3. Between 1960 and 1984, primary wood heating rates nearly tripled and electrical saturation rates increased by a factor of twelve to one.

Although the growth in wood fuel use appears to be largely related to changes in competing energy prices, household formation, and a shift toward electric homes with wood heat back-up (or homes with primary wood

TABLE 3

SATURATION RATES - MONTANA

Year	Natural Gas	Oil/ Kerosene	Coal	Wood	Electricity	Bottled Gas	Other
1960[1]	61.0%	19.0%	6.9%	5.8%	1.3%	5.2%	0.7%
1970[1]	69.5%	13.7%	2.1%	1.9%	3.9%	8.5%	0.3%
1980[1]	60.8%	5.9%	1.1%	8.9%	15.8%	7.3%	0.2%
1984[2]	57.4%	3.8%	1.0%	16.9%	16.1%	3.2%	1.5%

Sources:

[1] U.S. Department of Commerce, Bureau of the Census, 1982, "1980 Census, Detailed Housing Report."

[2] ECO Northwest, Ltd., wood fuel use telephone survey, 1984, conducted for Montana Department of Natural Resources and Conservation.

heat and electric heat back-up), there are other factors which may influence wood fuel consumption levels. Potential influences include consumer independence (the woodburner ethic) and air quality regulation.

The woodburner ethic, defined as a general consumer revolt against rising utility rates, involves both economic and noneconomic influences. In addition to reducing energy costs (real or perceived), consumers may also gain a sense of independence or enjoyment from converting to wood heat. The overall influence of the woodburner ethic, however, eludes quantification.

Similarly, the effect of both existing and potential air quality regulations is difficult to measure, and again involves both economic and noneconomic components. Burning restrictions in Missoula, for example, increase the real price of wood heat. Air quality degradation and its associated visual effect may even in the absence of formal restrictions cause woodburners to curtail use for noneconomic reasons. Furthermore, in view of the projected 60 percent increase in wood use (discussed in later sections of this report), it is probable that explicit pollution control requirements will be adopted in other Montana cities that currently do not have controls. (Public attitudes toward such influences are considered in the following chapter.)

One additional economic influence, not yet considered, involves the supply of firewood itself. With millions of acres of forest in Montana, it is difficult for many individuals to believe that filling a wood stove may become a luxury in some Montana cities and that conventional fuels, such as

natural gas and electricity, may be more economical. According to research done by the Bureau of Business and Economic Research (BBER) at the University of Montana, that is a likely possibility.[8]

Charles Keegan III, Research Associate for BBER and Director of the Bureau's Forest Products Industry Research, found that industry and the public have increased their use of wood fiber, and, as a result, the demand for dead and waste timber is increasing. This situation may create a shortage that will affect both users; however, one of the largest users of wood fiber, Champion International, does not agree and states:

> We have seen Keegan's research and we don't see any competition now or in the near term between Champion and those who heat with wood.[9]

In general, commercial woodcutters also believe that they are not, at least at the present time, competing with the timber industry for the same source of wood (see Chapter III).

The relative importance of each factor influencing wood consumption is analyzed in greater depth in the following sections of this report. The present chapter simply introduces likely causal variables affecting wood use and compares various estimates of total wood use. Since both wood use estimates and projections are uncertain, the following analysis utilizes a variety of procedures which include "wood expert" interviews, a public

---

[8] Charles E. Keegan III, "Demand For and Supply of Wood for Fuel and Fiber in Montana", unpublished paper, no date, University of Montana, Bureau of Business and Economic Research.

[9] Ernie Corrick, Champion International, Missoula, Montana, Energizer, Montana Power Company, December 1983.

opinion survey, and econometric and simulation techniques. The various methods are merged to the extent possible in order to maximize quantitative and qualitative sources of information. The interview and survey results are reported first.

III. WOOD FUEL USE SURVEYS

Telephone interviews were conducted with three groups of individuals (wood stove dealers, U.S. Forest Service timber staff officers, and commercial woodcutters) familiar with firewood costs and use. The information obtained from these interviews assisted in the design of the general public questionnaire.

The primary purpose of conducting the general public survey was to develop parameters for the wood simulation model. These parameters included estimating the current price of firewood, assessing change in wood use as a residential heating fuel, and evaluating noneconomic reasons why people do or do not burn wood to heat their homes.

The following sections describe the results of the "wood expert" telephone interviews and the general public survey. A discussion of how the general public's attitudes compare to the simulation model is presented in Chapter V.

A. Telephone Interviews - Wood Stove Dealers, Timber Staff Officers, and Commercial Woodcutters

Informal telephone interviews were conducted with the following groups:

1) Wood stove dealers in Helena, Bozeman, Billings, Great Falls, Missoula, Kalispell, and Butte.

2) Timber staff officers from the following national forests: Bitterroot, Beaverhead, Gallatin, Lewis and Clark, Deer Lodge, Lolo, Kootenai, and Flathead.

3) Commercial woodcutters from Helena, Bozeman, Great Falls, Missoula, Kalispell, and Butte.

It was not intended that these interviews would provide a statistical basis for evaluation, but rather improve insight and help to formulate the general public survey questionnaire. The interviews were informal in the sense that all questions were open-ended (i.e., no answer categories were provided). Each group was read the same set of questions; however, due to the open-ended questions, many individuals responded above-and-beyond the limits of the questions. Therefore, more information was gained from some of the individuals in each group than others. This is important to note because, for example, if one timber staff officer gave an unsolicited report of a particular behavior occurring in their national forest it does not necessarily mean this same behavior was or was not occurring in another national forest. It only conveys that one respondent was willing to offer more information than the other respondent--the very nature of informal, open-ended interviews.

1. Wood Stove Dealers

Ten wood stove dealers from seven Montana cities were queried about their perceptions of firewood use and customer attitudes. The yellow pages of the telephone directories were used to form the list of wood stove dealers to be interviewed.

Cost was reported by the majority of the wood stove dealers as the primary concern of people purchasing a wood stove. The wood stove dealers mentioned efficiency as the next important concern to wood stove purchasers and a few dealers thought air pollution emissions and useful life were important factors.

When purchasing wood stoves, customers usually do not explicitly evaluate the purchase in terms of an expected payback period. The dealers explained that the payback period varies, depending on the purchase. For example, the customer who buys only the wood stove will have a shorter payback period than the person who must purchase the stove, chimney, and special flooring.

In an attempt to elicit detailed responses from the wood stove dealers on their attitudes about savings associated with burning wood, the dealers were asked how much less expensive it is to use wood as compared to gas or electric space heat. Many of the dealers hedged their answers by responding "It depends on the cost of the wood." Some dealers thought heating with wood was less expensive than heating with gas or electricity if people cut their own wood. Several dealers, however, also mentioned that even though people thought of wood as "free," there are costs which are being ignored by these people. Dealers who did provide estimates of how much less costly wood heat is than gas or electric heat said it was 30 to 50 percent less expensive but did not provide the rationale for their estimate. These values are consistent with the simulation results in Chapter V.

When the dealers were questioned about the number of cords a household burns in an average winter for back-up heat and primary heat, their answers varied from one to ten cords for back-up heat and from three to 15 cords for primary heat. The dealers noted that the quantity of wood burned depended on such factors as the size of the home, the amount of insulation, the type of stove/fireplace, the weather, and the woodburning habits of the person.

The majority of the wood stove dealers thought that the use of firewood would increase over the next five years. The most prevalent reason given for this anticipated increase was that rising energy costs would encourage people to turn to using wood for heat. One dealer commented that individuals who gather or purchase wood to heat their homes pay a small amount at a time over the summer and do not realize the total cost of wood. To these people, it seems less expensive than paying large monthly heating bills during the winter.

The Butte, Bozeman, and Kalispell wood stove dealers indicated wood use would remain stable over the next five years because stove sales are decreasing, the novelty of wood is diminishing, stoves are becoming more efficient, and wood is getting more difficult to locate. A Missoula wood stove dealer was the only interviewee who thought there would be a decrease in wood use over the next five years. The reason given for this decrease was the belief that the use of wood pellets would replace unprocessed firewood.

The dealers were asked to estimate what proportion of wood they believe to be self-cut or purchased. Most of the dealers indicated that 60 to 70 percent of firewood is self-cut and 30 to 40 percent is purchased.

When the dealers were asked to estimate the proportion of replacement stoves that were purchased in comparison to new (i.e., customer's first wood stove), the most frequent response was 50 percent new and 50 percent replacement. Of those dealers who indicated most of their sales were for new stoves, some of them added that the number of customers purchasing replacement stoves was on the rise. One of the Missoula wood stove dealers, in fact, claimed that 75 percent of sales were replacement stoves.

The wood stove dealers were also asked to estimate what proportion of sales were fireplace inserts/heatalators compared to wood stoves. The answers varied from one percent fireplace inserts/heatalators to 99 percent stoves and from 70 percent fireplace inserts/heatalators to 30 percent wood stoves.

2. Timber Staff Officers

Telephone interviews were conducted with U.S. Forest Service timber staff officers from eight Montana national forests. The Helena National Forest timber staff officer was not interviewed because he was extensively consulted in the development of possible "wood expert" interview questions. It was believed that, because his opinions were instrumental in designing the interview questions, he was not an appropriate subject for additional comments.

Most of the officers based their estimate of number of cords of firewood cut in each national forest on the number of firewood permits issued. Estimates ranged from a low of 7,000 cords in the Bitterroot National Forest to a high of 50,000 in the Lolo National Forest. The Kootenai National Forest does not issue firewood permits; therefore, the officer was unable to provide an estimate of number of cords cut.

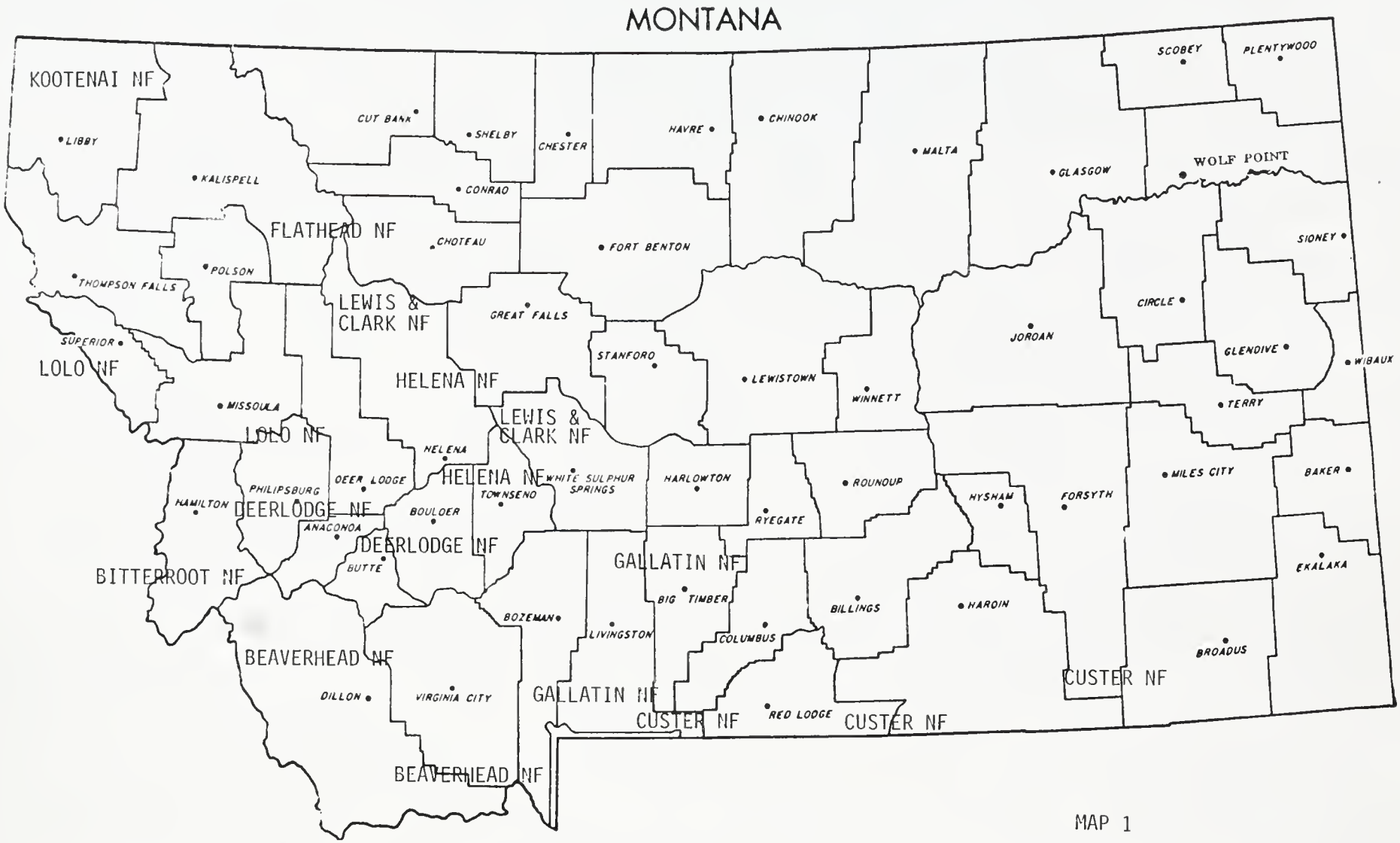
All of the timber staff officers believed that the harvesting of firewood had increased. Again, most of the officers based their estimates on the number of firewood permits issued as well as the number of pickup loads of wood that they had observed in their respective national forest. Estimates of the increase in firewood harvesting ranged from 25 to 500 percent.

The ideas provided by the timber staff officers on the kinds of policies/programs that could be designed to encourage increased cutting of firewood varied. Six of the officers thought firewood gathering could be increased if the wood supply could be made more accessible to the wood gatherers, that is, if there were more roads. The officers suggested building roads, piling slash closer to existing roads, and yarding wood nearer to roads as methods to increase wood accessibility. Two of the timber staff officers stressed the idea of educating people as to the beneficial effects to forests by harvesting firewood, while another officer suggested lower permit fees for underutilized areas.

The timber staff officers were asked to project firewood use over the next five years. Four officers indicated that they thought firewood use would increase over the next five years because of rising energy prices, whereas four officers thought firewood use would remain stable. Reasons given for this perceived stability included: wood gatherers are realizing that wood is not "free" and people have started to accept high energy costs. The Lewis and Clark timber staff officer thought that firewood use would decrease over the next five years because the firewood supply would diminish.

When asked what proportion of wood is self-cut or purchased, three of the timber staff officers declined to answer because they were uncertain of the proportion. Estimates that were provided by the officers ranged from 85 to 95 percent self-cut and five to 15 percent purchased.

The following list identifies the localities from which timber staff officers reported most individuals come to cut firewood in each national forest (see Map 1) as well as some distances driven to gather and transport wood.



MAP 1

MONTANA NATIONAL FORESTS

1) Beaverhead National Forest: Dillon, Butte, Deer Lodge, and the Bitterroot Valley.

2) Bitterroot National Forest: Primarily within the Bitterroot Valley, with an average round trip distance of 40 to 60 miles.

3) Custer National Forest: Primarily from the Billings area.

4) Deer Lodge National Forest: Butte, Anaconda, and Whitehall.

5) Flathead National Forest: Kalispell, Big Fork, Whitefish, Columbia Falls, and the Polson-Ronan area.

6) Gallatin National Forest: Bozeman, West Yellowstone, Ennis, and Billings.

7) Kootenai National Forest: Troy, Libby, Eureka, and Bonner's Ferry (Idaho).

8) Lewis and Clark National Forest: Approximately 80 percent from Great Falls with an average round trip of 160 to 180 miles.

9) Lolo National Forest: Missoula, Spokane (Washington), and Cour D'Alene (Idaho).

3. Commercial Woodcutters

Interviews were conducted with ten commercial woodcutters who had placed classified advertisements to sell firewood and who cut more than ten cords of firewood per year. The length of time that the commercial firewood cutters have been in business ranged from one to 15 years. Four have been in business one year; one, two years; one, three years; two, four years; one, six years; and one, 15 years.

Nine of the commercial woodcutters believed they were not competing with the timber industry for the same source of wood, while one cutter was

unsure whether he was in competition for this wood. Most of the woodcutters reported they had harvested trees that the timber industry would not use, including dead timber, down timber, and crooked trees. One cutter added that he cut in areas already commercially harvested, while another cutter remarked that the areas where he obtained Forest Service bids to cut firewood were small and inaccessible to the timber industry woodcutters.

The woodcutters were asked to estimate the number of cords that a household burns during an average winter for back-up or primary heat. The estimates for back-up heat ranged from one to 16 cords, and for primary heat from five to 16 cords. Most of the woodcutters remarked that the number of cords burned was influenced by the weather, the size of the house, and the amount of insulation in the house.

The estimated cost of a cord of wood split, stacked, and delivered ranged from $50 to $75 per cord, with the most frequent response being $60 to $65. Five cutters did not know the price of wood five years ago, but the estimates provided by five of the woodcutters were: $45, $50, $45 to $60, $60, and about the same as the current price.

The majority of the commercial woodcutters thought the price of firewood would increase over the next five years. The most prevalent reason given to support this answer was that firewood is becoming more difficult to obtain because people must drive further to obtain it. Other reasons included the price of goods and services are increasing and more homes are being equipped to burn wood.

Three of the woodcutters thought the price of firewood would remain stable over the next five years because of the increased competition of more people cutting and selling firewood which keeps prices down. One cutter would not speculate about the price, and no woodcutters projected a decrease in the price of firewood.

Seven of the commercial woodcutters thought the use of firewood for heating would increase over the next five years. Reasons given for this increase were the rising price of electricity and gas, bad weather, persons who are using firewood will continue to use it, and it has increased every year. Three cutters thought firewood use would remain stable over the next five years because air pollution laws may be passed which would limit burning to some extent and because woodstoves are expensive to purchase and install.

B. General Public Survey

The interviews conducted with the "wood experts" provided useful information in designing the general public questionnaire. The topics which were influenced by the interviews included cost and price of firewood, payback period for woodburning stoves/fireplaces, and firewood supply issues.

The following sections highlight the results of the general public survey. (For a complete listing of all survey response frequency distributions, see Appendix A). A total of 603 interviews were completed, with 387 of these interviews being MPC customers (see Appendix B for sampling technique). As specified in the contract, the MPC electrical service area was emphasized; therefore, MPC customer responses will appear both in the Montana total and as a separate entity.

1. Woodburners Survey

Of the 603 total completed interviews, 46.6 percent (281 respondents) indicated they have either a workable wood stove or woodburning

fireplace in their home. In woodburning surveys conducted in the Missoula Valley, Church reported that in the 1976-77 survey 37.7 percent indicated that they burn wood in their residence or garage compared to 53.1 percent in the 1979-80 survey. Church stated:

> This increase [40.8 percent] is largely attributable to rapidly rising energy costs and, to a lesser degree, the desire to conserve fossil fuels by switching to a renewable energy source. Also, having a wood stove has become a somewhat fashionable trend in the community.[10]

Table 4 presents data on the number of fireplaces or wood stoves in the respondents' homes. "One wood stove or fireplace with stove insert" was the most prevalent answer by respondents (both at the State and MPC levels).

When the respondents were asked when they had installed their most recent fireplace or wood stove (Table 5), the response was almost evenly divided between "came with house" (42.7 percent) and "1 to 5 years ago" (44.1 percent). As can be seen on Table 5, the trend of purchasing wood burning devices has increased substantially over the last five years.

When the general public survey participants were queried whether the wood stove or fireplace that they had installed was a replacement for an existing unit, 80.1 percent (129 respondents) answered "no." Approximately the same percent of MPC customers (81.3 percent) indicated their wood stove or fireplace was not a replacement unit. The majority of wood stove dealers, however, estimated that 50 percent of their sales were new and 50 percent replacement units. This 30 percent difference between the

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[10] Scott Church (principal researcher), "Residential Wood Burning and Its Impact on Particulate and Carbon Monoxide Emissions in the Missoula urban Valley, 1979-80." 1980, prepared for the Missoula City-County Health Department, Air Quality Unit.

TABLE 4

NUMBER OF FIREPLACES, WOOD STOVES, OR FIREPLACES WITH INSERTS IN RESPONDENTS' RESIDENCES

Woodburning Device	State of Montana	MPC Service Area
A. Fireplaces		
None	61.9%	56.3%
One	32.0%	36.1%
Two	5.7%	7.1%
Three	0.4%	0.5%
More than three	0.0%	0.0%
	N = 281	N = 183
B. Wood Stoves or Fireplaces with Stove Insert		
None	29.5%	36.6%
One	62.3%	55.7%
Two	8.2%	7.7%
Three	0.0%	0.0%
More than three	0.0%	0.0%
	N = 281	N = 183

Note: The question asked the respondents to indicate the number of fireplaces and the number of wood stoves in their home; therefore, the respondents could have answered in more than one category. The percent is based on the total number of respondents participating in the woodburners survey (281).

TABLE 5

TIME PERIOD IN WHICH RESPONDENTS
INSTALLED MOST RECENT FIREPLACE OR WOOD STOVE

Time Period	State of Montana	MPC Service Area
Came With House	42.7%	47.5%
1 To 5 Years Ago	44.1%	41.0%
6 To 10 Years Ago	9.3%	8.2%
More Than 10 Years Ago	3.9%	3.3%
	N = 281	N = 183

respondents and wood stove dealers may be simply due to the small number of dealers who were interviewed.

When the survey participants were asked the approximate cost of purchasing and installing their wood stove or fireplace, the following responses were recorded: 30.4 percent (49 respondents) "less than $500," 32.3 percent (52 respondents) "$500 to $900," 14.3 percent (23 respondents) "$901 to $1300," and 9.9 percent (16 respondents) "more than $1300." The MPC customer respondents' answers were nearly the same as the State as a whole. Table 6 presents a comparison of the woodburners' reported actual costs and the nonwoodburners perceived costs in purchasing and installing a wood stove or fireplace. From this data, it can be surmised that the nonwoodburners think the cost of purchasing and installing a woodburning device exceeds the actual cost reported by the woodburners.

Although the wood stove dealers believed their customers do not explicitly evaluate a "payback" period on their stove purchase, approximately 88 percent (142 respondents) thought their wood stove or fireplace would pay for itself (see Table 7). Moreover, 48.6 percent (69 respondents) believed the payback period would be from "1 to 2 years" and 31.7 percent (45 respondents) thought "3 to 5 years." This perceived rapid payback is generally consistent with the price response estimates discussed in Chapter IV. Nevertheless, fuel cost savings developed in the simulation runs in Chapter V suggest that actual annual savings are comparatively low. A six-year payback may be more realistic. (This assumes a $1,000 stove in 1984 dollars, $220 average annual real price savings, $35 per cord in real terms, and a 6 percent real interest rate).

TABLE 6

ACTUAL (WOODBURNERS) VERSUS PERCEIVED (NONWOODBURNERS)
COST TO PURCHASE AND INSTALL WOOD BURNING DEVICE

Wood Stove/Fireplace Price	Woodburners		Nonwoodburners	
	State of Montana	MPC Service Area	State of Montana	MPC Service Area
Less than $500	30.4%	27.1%	12.0%	6.7%
$500 to $900	32.3%	34.4%	28.0%	26.7%
$901 to $1300	14.3%	17.0%	36.0%	33.3%
More than $1300	9.9%	10.4%	20.0%	26.7%
Don't Know/Refused	13.0%	10.4%	4.0%	6.7%
	N = 161	N = 96	N = 25	N = 15

TABLE 7

RESPONDENTS' PERCEPTION OF PAYBACK PERIOD
FOR WOOD STOVE OF FIREPLACE

Payback Period	State of Montana	MPC Service Area
1 To 2 Years	48.6%	43.4%
3 To 5 Years	31.7%	34.9%
6 To 8 Years	6.3%	4.8%
More Than 8 Years	4.9%	6.0%
Don't Know/Refused	8.5%	10.8%
	N = 142	N = 83

The majority of the woodburners interviewed had burned wood for more than three years. Table 8 presents the approximate number of cords burned by the respondents in the past three years. It appears from the data that there is little variance in the number of cords burned by the respondents from year-to-year.

Approximately 69 percent (193 respondents) of the woodburners interviewed generally cut their own wood, with more than 90 percent indicating that they prefer to cut their own wood because "it is cheaper to cut than to buy" and/or they "consider it a form of recreation." When asked how much less per cord they thought it was to cut rather than to buy firewood, the following answers were recorded: 11.4 percent (22 respondents) "don't think it costs less," 4.7 percent (9 respondents) "$10 less," 11.4 percent (22 respondents) "$20 less," and 37.3 percent (72 respondents) "$30 less." Although the majority of the respondents thought it costs less to cut wood than to purchase it, the wood stove dealers noted that many people may visualize the wood as being "free" but that there were costs being ignored by these people.

The commercial woodcutters were asked to estimate the cost of a cord of wood. The most frequent response was $60 to $65. The most prevalent price indicated by the woodburner respondents (27.3 percent or 24 respondents) was "$40 to $50." Other responses included: "less than $40" (12.5 percent or 11 respondents), "$51 to $60" (21.6 percent or 19 respondents), "$61 to $75" (15.9 percent or 14 respondents), and "more than $75" (2.3 percent or 2 respondents). The responses of MPC customers were very similar to the State responses.

The majority of the woodburners thought they would burn about the same amount of wood for the next five years as they burned this winter,

TABLE 8

NUMBER OF CORDS OF WOOD BURNED BY RESPONDENTS
IN 1981-82, 1982-83, AND 1983-84

Number of Cords	State of Montana	MPC Service Area
A. 1981-82		
Less than 1 Cord	20.6%	27.4%
1 to 2 Cords	18.6%	20.5%
3 to 4 Cords	19.6%	19.7%
5 to 6 Cords	13.4%	10.3%
More than 6 Cords	17.5%	14.5%
Don't Know/ Refused	10.3%	7.7%
	N = 194	N = 117
B. 1982-83		
Less than 1 Cord	21.1%	28.0%
1 to 2 Cords	21.1%	23.8%
3 to 4 Cords	18.1%	16.1%
5 to 6 Cords	15.0%	12.6%
More than 6 Cords	14.5%	11.9%
Don't Know/ Refused	10.1%	7.7%
	N = 227	N = 143
C. 1983-84		
Less than 1 Cord	24.6%	30.0%
1 to 2 Cords	23.5%	24.7%
3 to 4 Cords	20.9%	20.0%
5 to 6 Cords	11.9%	10.6%
More than 6 Cords	12.3%	10.0%
Don't Know/ Refused	6.7%	4.7%
	N = 268	N = 170

Note: Variation between responses for the three years of reported wood use are not statistically significant.

providing the weather was the same as this past winter. Some of the reasons provided by these 34 respondents were: "utility prices may go up" (29.4 percent or 10 respondents), "anticipate buying a more efficient stove" (5.9 percent or 2 respondents), and "wood is a cheaper way to heat my home" (17.6 percent or 6 respondents). In contrast, the majority of "wood experts" believed that firewood use would increase, presumably because of household formation. Following is a brief summary of the "wood expert" interviews regarding firewood use:

1) Wood Stove Dealers: The majority thought use would increase over the next five years due to rising energy costs. Of those dealers who thought it would remain stable, reasons provided were: the novelty of burning wood was decreasing and firewood would become more difficult to find.

2) Timber Staff Officers: The responses were evenly divided between firewood use increase and stability. Those who thought use would increase attributed it to rising energy prices and those who believed use would remain stable based their opinion on woodburners' realization that wood is not free and the acceptance of high energy prices.

3) Commercial Woodcutters: The cutters who thought firewood use would increase provided the following reasons: rising price of electricity and gas, bad weather, current woodburners will continue to burn wood, and firewood use has always increased on an annual basis. Air pollution laws and the expense involved with wood stove purchase and installation were reasons given by those cutters who thought use would remain stable.

The woodburner respondents were read several statements about heating with wood and asked whether they agreed or disagreed with the

statements (see Appendix A). A similar set of statements was read to the nonwoodburners. Table 9 presents the responses for common questions presented to woodburners, nonwoodburners who were considering a wood stove purchase, and nonwoodburners who were not considering a wood stove purchase. Among the most agreed upon statement for both woodburners and nonwoodburners was "heating with wood causes extra housecleaning chores." Nonwoodburners and woodburners, however, have a different perception of pollution. Woodburners think that heating with wood is less polluting than do the nonwoodburner group.

2. Nonwoodburners Survey

Approximately 53 percent (322 respondents) were included in the nonwoodburner survey. Of this number, 52.7 percent (204 respondents) were MPC customers. Eight percent (25 respondents) indicated they had recently considered installing a wood stove or fireplace.

The nonwoodburners survey was divided into two sections--those respondents who have not recently considered installing a wood stove or fireplace (92.2 percent or 297 respondents) and those respondents who have considered this option (7.8 percent or 25 respondents). For the most part, the nonwoodburners survey as discussed in this section is concerned with only a small number of respondents (25). This small number does not allow for valid statistical inferences to be made because the cell blocks (i.e., answer categories) contain only a few responses.

The 297 respondents were not questioned about costs involved with purchasing, installing, or maintaining a wood stove or fireplace; rather, they were only asked to express their opinion (agree or disagree) with three statements about heating with wood and to estimate the age of their home. The responses to these statements are presented in Table 9.

TABLE 9

COMPARISON OF VIEW OF WOODBURNERS AND
NONWOODBURNERS WITH STATEMENTS CONCERNING HEATING WITH WOOD

Statement	Woodburners		Nonwoodburners Considering Stove Purchase		Nonwoodburners Not Considering Stove Purchase	
	Agree	Disagree	Agree	Disagree	Agree	Disagree
Heating with wood is to inconvenient	44.8%	53.7%	28.0%	72.0%	50.2%	42.8%
Heating with wood causes extra house-keeping chores	75.1%	24.2%	88.0%	12.0%	71.7%	22.9%
Woodburning is a major source of air pollution	44.5%	50.9%	72.0%	28.0%	57.6%	36.0%
	N = 281		N = 25		N = 297	

Note: Percents may not sum to 100% because some respondents may have refused to answer the question.

Table 10 presents the type of woodburning device that the 25 respondents thought they would install. Most of the survey participants were considering the installation of a wood stove or fireplace with an insert.

Eighty percent of the survey participants who were considering the installation of a wood stove or fireplace believed they would cut their own firewood. Furthermore, most of the respondents (40.0 percent or 8 respondents) thought if they cut their own wood it would cost less than $20 per cord. Fifteen percent (three respondents) indicated self-cut firewood would cost between $20 and $30, 10.0 percent (two respondents) indicated between $31 and $50, and 5.0 percent (one respondent) more than $50 per cord. Answers recorded for the MPC customer respondents were as follows: 42.9 percent (six respondents) "less than $20," 7.1 percent (one respondent) "$20 to $30," 7.1 percent (one respondent) "$31 to $50," and 7.1 percent (one respondent) "more than $50."

When queried on how much they believed it would cost to purchase a cord of wood, the nonwoodburner survey participants were provided the same answer categories as the woodburner respondents. Table 11 presents the comparison between the two groups' answers. The largest discrepancy between the two groups was in the answer category "more than $75" to purchase a cord of wood, with 20 percent of the nonwoodburners perceiving this was the amount they would pay and 2.3 percent of the woodburners indicating they pay this amount. This discrepancy is even more noticeable when comparing the MPC nonwoodburners and MPC woodburners (33.3 percent and 2.7 percent, respectively). It should be noted, however, that the number of nonwoodburners who responded to this question is extremely small.

TABLE 10

TYPE OF WOOD STOVE OR FIREPLACE
NONWOODBURNER RESPONDENTS WOULD INSTALL

Type of Woodburning Device	State of Montana	MPC Service Area
Fireplace	0.0%	0.0%
Fireplace with Heatalator	4.0%	6.7%
Wood Stove or Fireplace with Insert	72.0%	66.7%
Both Fireplace and Wood Stove	8.0%	0.0%
Don't Know/Refused	16.0%	26.7%
	N = 25	N = 15

TABLE 11

PERCEIVED (NONWOODBURNERS) VERSUS ACTUAL (WOODBURNERS)
COST TO PURCHASE A CORD OF WOOD

Amount Paid for Cord of Wood	Nonwoodburners		Woodburners	
	State of Montana	MPC Service Area	State of Montana	MPC Service Area
Less than $40	8.0%	6.7%	12.5%	13.7%
$40 to $50	24.0%	13.3%	27.3%	26.0%
$51 to $60	24.0%	20.0%	21.6%	20.5%
$61 to $75	12.0%	13.3%	15.9%	12.3%
More than $75	20.0%	33.3%	2.3%	2.7%
Don't Know/Refused	12.0%	13.3%	20.5%	24.7%
	N = 25	N = 15	N = 88	N = 73

Thirty-six percent (nine respondents) thought it would cost "$901 to $1300" to purchase and install a wood stove or fireplace in their home. Twenty percent (five respondents) thought the price would be "more than $1300," 12.0 percent (three respondents) "less than $500," and 28.0 percent (seven respondents) "$500 to $900." These perceived costs are high when compared to the woodburner's reported actual costs (see Table 9), but, again, the number of nonwoodburner responses is too small to allow for valid estimates.

The majority of the survey participants (76.0 percent or 19 respondents) thought it was less expensive to heat with wood than with gas, electricity, fuel oil, or propane. Some reasons why these respondents do not heat with wood even though they believe it is less expensive to do so, are presented in Table 12. This table shows the responses to statements in which the nonwoodburner survey respondents were asked to agree or disagree. As with all other survey respondents, "heating with wood causes extra housecleaning chores" received the most frequent number of responses.

TABLE 12

RESPONDENTS' AGREEMENT OR DISAGREEMENT
WITH STATEMENTS CONCERNING HEATING WITH WOOD

Statement	State of Montana		MPC Service Area	
	Agree	Disagree	Agree	Disagree
Heating with wood is too inconvenient	28.0%	72.0%	20.0%	80.0%
Heating with wood causes extra house-cleaning chores	88.0%	12.0%	80.0%	20.0%
Woodburning is a major source of air pollution	72.0%	28.0%	73.3%	26.7%
Before I would install a wood stove or fireplace, firewood would have to be easier to gather	20.0%	80.0%	13.3%	86.7%
Wood costs would have to go down before I would install a wood stove or fireplace	8.0%	92.0%	6.7%	93.3%
The cost of a wood stove or fireplace would have to go down before I would install one	20.0%	80.0%	33.3%	66.7%
Before I would install a wood stove or fireplace, they would need to be less polluting	44.0%	56.0%	53.3%	46.7%
	N = 25		N = 15	

IV. WOOD FUEL FORECASTING

A. Forecasting Methodology

Data availability often determines the type of forecasting methodology (end use simulation, econometric models, systems simulation, or hybrid combinations). Typically, all techniques employ the same basic philosophy; that is, they all attempt to reduce a complex set of related variables to a set of fundamental causal factors and accounting equations. Econometric approaches are usually more aggregate in nature (fewer variables) and are derived on the basis of past experience. In other words, the response/linkage coefficients are generated from historical data. End use models, on the other hand, may employ an econometric price response specification when data are available, and usually are more disaggregated, particularly when the coefficients are developed on the basis of engineering estimates and various assumptions about saturation/penetration rates, diffusion timing, and comparisons of least-cost alternatives. In any event, data must be available to develop and calibrate the system.

The systems simulation method is a more ad hoc approach to modeling where the source of the central coefficients are assumed (a priori) since either few or no data are available. While the approach may offer theoretical appeal, the lack of real data and the resultant inability to quantify the influence of variables on each other generally makes the outcome of such systems more suspect because the linkages can neither be denied nor proven. Nevertheless, when information is limited, the systems method is often the only possibility open to test the implications of the

analyst's "priors" (initial input values) against the outcome of the simulation.

The DNRC and ECO had originally contemplated the development of an econometric wood use forecasting system since the primary advantage of an econometric specification rests in the ability to quantify price/use response linkages on the basis of historical data. It was believed that an analysis of the DOE residential wood use data as well as household formation would help determine how sensitive wood use levels were to economic and demographic variables, specifically competing energy prices.

A traditional econometric specification was not possible since no wood price data exist. Attempts to derive a Montana wood purchase price series were unsuccessful but, nevertheless, do "suggest" that real wood (purchase) prices have been relatively stable at approximately $50 to $60 in 1984 dollars. Sample prices were derived from six major Montana urban newspapers (Sunday issues, August through November, for 1970, 1975, and 1980), but were expressed in such form (cost per pickup load, cord, weight, four foot sections, cut, split, delivered) as to make consistent annual prices (estimates) impractical. Therefore, the econometric form, once hoped for, was abandoned. In other words, without wood price data, neither direct nor cross elasticity coefficients can be estimated. General wood use (DOE estimate) response to other variables is discussed in the following section.

In the present wood forecasting case, the DNRC and ECO determined that the most appropriate forecasting method should employ the systems

simulation approach. The primary reasons for this choice were: 1) there was concern over the accuracy of the DOE wood use estimates and there were no wood price data which made a strict reliance on a traditional econometric specification unworkable, 2) insufficient data also precluded detailed end use specification, and 3) the DNRC was interested in developing a system with numerous economic and engineering inputs, allowing for a high level of simulation flexibility.

B. Price Response

The DOE state estimates of wood use per household were used to develop price and consumption response coefficients. Two different investigations were performed: 1) analysis of cross-section time series data (50 states for 1970, 1975, and 1980), and 2) analysis of Montana time series data (1970-80). The cross-section analysis included the following variables:

Variable	Definition	Source
USE	Wood use per household	Department of Energy
P/N	Nominal price fuel	Department of Energy
FOR	Percent of land forested	Statistical Abstract
URB	Percent urban	Bureau of Census
Y/N	Nominal per capital income	Department of Commerce
HDD	Heating degree days	Department of Energy
P/R	Real price fuel	Department of Commerce
Y/R	Real income	Department of Commerce

The only variable requiring explanation is the price variable which is the efficiency weighted average energy price in 1980 dollars per million delivered BTUs. This variable is defined as:

$$\text{Price} = \sum_{i=1}^{4} SAT_i * (P_i * 1/E_i)$$

Where SAT = saturation (gas, electric, oil, and propane)

P = price (gas, electric, L/P, and oil) per million BTUs in 1980 dollars.

E = conversion efficiency (gas, electric, oil, and propane)

Where conversion efficiency rates for each category are:

Gas = 0.6

Electric = 1.0

L/P = 0.6

Oil = 0.5

The simple correlations generated by the cross-section data set are shown in Table 13. The correlations reveal the following rather obvious patterns. Wood use per household is:

1) Directly related to competing energy prices.

2) Directly related to the percent of the land base in forest.

3) Lower in urban areas than in rural areas.

4) A direct but weak function of per capita income.

5) A direct function of heating requirements.

Table 14 presents the regression equation that was generated from the 50 state, three-year time series. In this case, use per household by state is a function of the percent of land in forest, the percent of urban population, heating degree days, and the average real price of competing fuels.

Sensitivity of household wood use to changes in the price of competing fuels was calculated by doubling the real mean price of other fuels and holding the other three variables constant. At a mean price of $7.48 per million BTU, average use for all households was estimated to

TABLE 13

CORRELATION COEFFICIENTS

Variable	Definition	Use
USE	Wood use per household	1.00
P/N	Nominal price fuel	.37
FOR	Percent of land forested	.43
URB	Percent urban	-.49
Y/N	Nominal per capital income	.22
HDD	Heating degree days	.21
P/R	Real price fuel	.29
Y/R	Real income	-.12

Number of Cases: 150

TABLE 14

REGRESSION ANALYSIS
BASED ON 50 STATE, 3-YEAR TIME SERIES DATA

Number of Cases: 150 Number of Variables: 8

Index	Name	Mean	STD.DEV.
1	P/N	5.690	3.519
2	FOR	41.160	22.258
3	URB	66.359	14.329
4	Y/N	6,185.040	2,451.083
5	HDD	5,114.093	2,189.309
6	P/R	7.481	2.816
7	Y/R	8,578.280	1,398.895
DEP.VAR:	USE	.519	.332

Dependent Variable: USE PER HOUSEHOLDS (ALL HOUSEHOLDS)

VAR.	REGRESSION COEFFICIENT	STD. ERROR	F(1,145)	PARTIAL R^2
FOR	.0042	.0011	14.622	.0916
URB	-.0092	.0016	33.311	.1868
HDD	.0001	.0001	8.801	.0572
P/R	.0282	.0082	11.814	.0753
CONSTANT	.5925			

STD.ERROR OF EST = .255
R SQUARED = .423
MULTIPLE R = .651

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO
REGRESSION	6.936	4	1.734	26.617
RESIDUAL	9.446	145	.065	
TOTAL	16.382	149		

be 0.52 cords per year. When price was doubled to $14.96, household use rose to 0.73 cords, or a 40 percent increase. Little, if anything, is known about changes in the price of wood over the base period, so the 40 percent increase in wood associated with a doubling of other energy prices cannot be viewed as a formal elasticity measure.

In terms of the regression estimates of average household wood use in Montana, the cross-section procedure understated the 1970 and 1975 value by approximately 0.1 cord but was low by 0.6 cord or 50 percent by 1980. The estimation procedure failed to capture the rapid increase in wood consumption in Montana between 1975 and 1980, probably resulting from a doubling of natural gas prices. Another study reached the opposite conclusion; that is, Montana used significantly less wood than expected, illustrating the high level of estimation error in wood use analysis or forecasting.[11]

A second regression specification was explored, this time based on Montana time series data. In this case, wood use per household (from DOE and Census estimates) was expressed as a function of the real price per million BTU as discussed earlier. (The results of this procedure are shown in Table 15.) There was an 182 percent increase in household consumption associated with a 100 percent rise in the real price of other fuels (as measured from the mean value 1970-80). This may suggest that residential wood use is extremely responsive to the price of other fuels.

The reader should note that the use/price sensitivity of the cross-section specification was significantly less than the result of the Montana

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[11] F.W. Lipfert and J.L. Dugan, "Residential Firewood Use in the United States," Science, (March 1983), Vol 219.

TABLE 15

REGRESSION ANALYSIS
BASED ON MONTANA TIME SERIES DATA

DEPENDENT VARIABLE: USE PER HOUSEHOLD (ALL HOUSEHOLDS)

VAR.	REGRESSION COEFFICIENT	STD. ERROR	F(1, 9)
PRICE	.2236	.0535	17.491
CONSTANT	-.5351		

STD. ERROR OF EST. = .132
R SQUARED = .660
R = .813

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO
REGRESSION	.303	1	.303	17.491
RESIDUAL	.156	9	.017	
TOTAL	.459	10		

time series. No definitive conclusions can be drawn which explain the difference in price sensitivity between the two specifications. Nevertheless, the two estimates help to bracket the range of price response parameters which are utilized in the following simulation system.

C. Specification of the Simulation Model

Table 16 presents the variables which were selected for inclusion into the simulation system entitled WEST (Wood Estimation Simulation Technique). The primary linkages between variables are shown in Figure 3. The logic of the model is straightforward and can be described in terms of the following general steps:

1) Calculate the total number of households.

2) Project real wood, gas, and electric energy costs per million BTU.

3) Project efficiency levels and saturation rates for gas, electric, and wood heat (efficiency only).

4) Calculate real average energy costs for wood and other fuels (gas and electric).

5) Calculate real capacity costs of energy for wood and other fuels (gas and electric).

6) Calculate total real energy costs for wood and other fuels, given total heat load requirements.

7) Calculate real fuel cost savings for wood versus other fuels (both energy and capacity costs).

8) Calculate saturation rate wood, given average cost savings from wood.

TABLE 16

INPUT PARAMETERS

Variables	Variable Name
Years	
Number of Years in Forecast	(n)
Household Formation	
Initial Number of Households	(HS)
Household Growth Rate	(HSG)
Heat Load Requirements	
Average BTU Requirement Per House (in millions)	(BTUR)
Change in Heat Load Requirement (i.e., growth rate in efficiency)	(BTURG)
Efficiency	
Conversion Efficiency Wood	(WE)
Growth Rate in Efficiency Wood	(EWG)
Conversion Efficiency Gas	(EG)
Growth Rate in Efficiency Gas	(EGG)
Conversion Efficiency Electricity...Assumed to be 100%	
Price	
Price Wood ($ Cord)	(PW)
Heat Output Per Cord (Million BTUs)	(BTUW)
Price Wood Growth (Annual % Rate)	(PWG)
Price Gas ($ Million BTU)	(PG)
Price Gas Growth (Annual % Rate)	(PGG)
Price Electricity (Annual $ Per Million)	(PE)
Price Response	
Elasticity Wood	(EW)
Elasticity Other Fuels	(EO)
Time Response Adjustment	(GAMMA)

TABLE 16 (Cont'd)

Saturation Rates	
Saturation Rate Gas (Initial)	(SATG)
Saturation Rate Electricity (Initial)	(SATE)
Saturation Rate Wood (Initial)	(SATW)
Saturation Gas Growth (Annual % Change)	(SATGG)
Saturation Electricity Growth (Annual % Change)	(SATEG)
Wood Use Per Household	
Cords Per Household With Woodburning Device (Initial)	(Q)
Capacity and Operational Costs	
Price Wood Stove ($)	($STOVE)
Price Electric Heat ($)	($ELECT)
Price Gas Heat ($)	($GAS)
Interest Rate (%)	(i)
Term Wood (Years)	(nw)
Term Other (Years)	(no)
Operation, Maintenance, Repair Wood (% of Annual Capacity Costs)	(OMRW)
Operation, Maintenance, Repair Other (% of Annual Capacity Costs)	(OMRO)
Wood Cost Perception Adjustment	(DW)
Other Cost Perception Adjustment	(DO)
Maximum Output Per Stove (Millions of BTUs Per Year)	(WMAX)
Other Costs Wood	
Cost Inconvenience (%)	(CI)
Pollution Impact (%)	(PI)
Woodburner Ethic (%)	(WBE)
Dummy Wood Cost ($ Per Million BTUs)	(DUM)
Saturation Rate Conversion	
Wood Conversion Coefficient	(C)

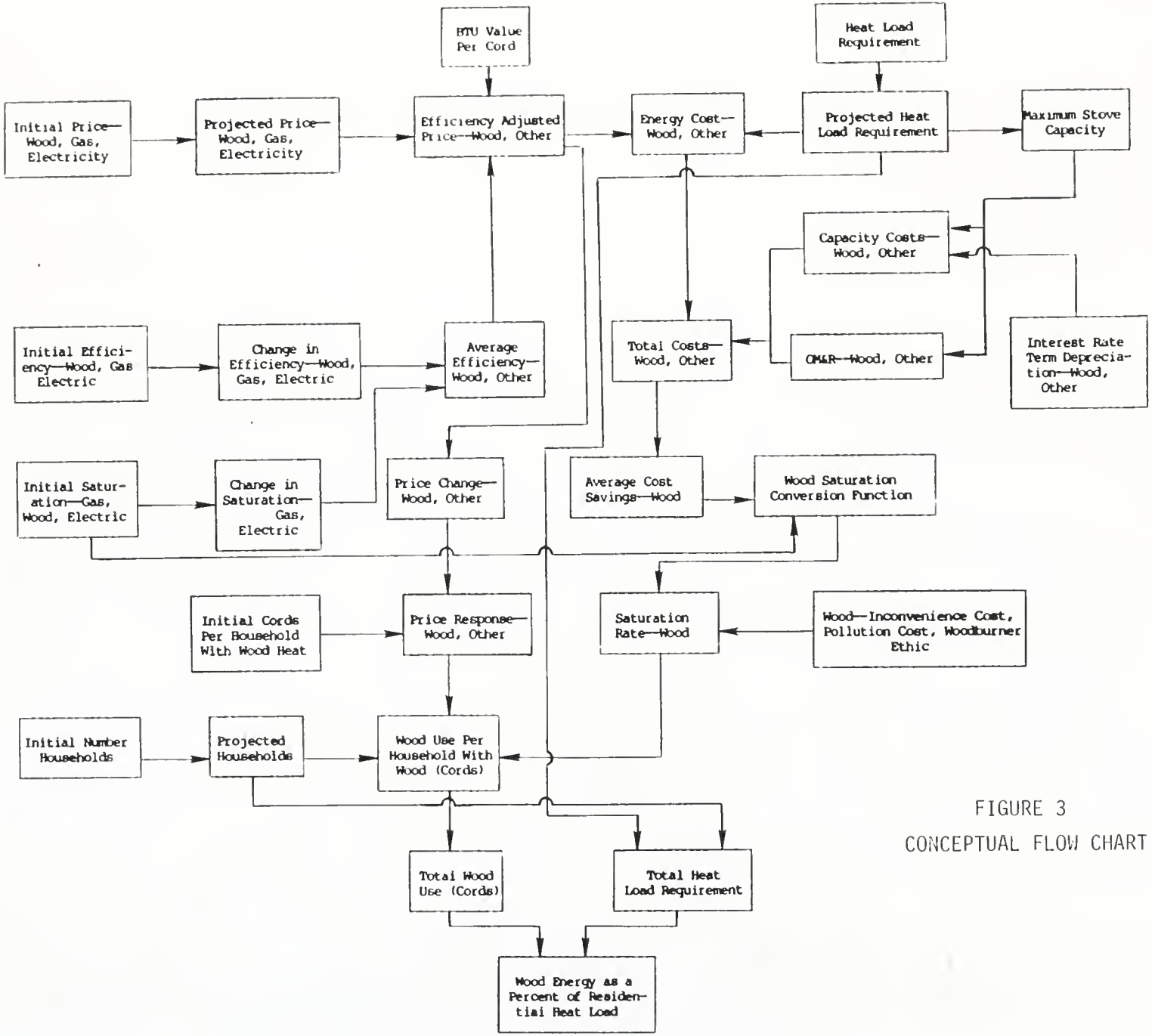
BTU Value Per Cord
Heat Load Requirement
Initial Price—Wood, Gas, Electricity
Projected Price—Wood, Gas, Electricity
Efficiency Adjusted Price—Wood, Other
Energy Cost—Wood, Other
Projected Heat Load Requirement
Maximum Stove Capacity
Capacity Costs—Wood, Other
Initial Efficiency—Wood, Gas Electric
Change in Efficiency—Wood, Gas, Electric
Average Efficiency—Wood, Other
Total Costs—Wood, Other
O&M—Wood, Other
Interest Rate Term Depreciation—Wood, Other
Initial Saturation—Gas, Wood, Electric
Change in Saturation—Gas, Electric
Price Change—Wood, Other
Average Cost Savings—Wood
Wood Saturation Conversion Function
Initial Cords Per Household With Wood Heat
Price Response—Wood, Other
Saturation Rate—Wood
Wood—Inconvenience Cost, Pollution Cost, Woodburner Ethic
Initial Number Households
Projected Households
Wood Use Per Household With Wood (Cords)
Total Wood Use (Cords)
Total Heat Load Requirement
Wood Energy as a Percent of Residential Heat Load

FIGURE 3

CONCEPTUAL FLOW CHART

9) Calculate amount of wood used per household with wood heat, given change in wood and other energy prices.

10) Calculate total wood use (i.e., total number of houses times wood saturation times wood use per household).

11) Calculate total heat load (i.e., number of houses times heat load per house).

12) Calculate wood energy use as a percent of total heat load.

13) Repeat until end of forecast period.

D. Specific Algorithms

Variable names are shown in Table 16. For a more complete review, see the actual computer code in Appendix C. For t equal to years 2 through n the specific algorithms of the model are as follows.

1) NPW = (PW + DUM)

Where NPW = new price wood

2) HS_t = (HS * (1 + (HSG/100))$^{t-1}$)

Where HS_t = households, year t

3) PW_t = ((NPW/((EW * (1 + (EWG/100))$^{t-1}$))/BTUW) * (1 + (PWG/100))$^{t-1}$)

Where PW_t = price wood adjusted for heating efficiency, year t

4) PG_t = ((PG/(EG * (1 + (EGG/100))$^{t-1}$)) * (1 + (PGG/100))$^{t-1}$)

5) PO_t = ((((SATG * (1 + (SATGG/100))$^{t-1}$) * PG_t) + ((SATE * (1 + (SATEG/100))$^{t-1}$) * PE_t)) * (1/((SATG * (1 + (SATGG/100))$^{t-1}$) + (SATE * (1 + (SATEG/100))$^{t-1}$))))

Where PO_t = weighted price gas and electricity

6) PWC = (((\$STOVE * (i/(1 - (1 + i)$^{-nw}$))) * (1 + (OMRW/100))) * DW)

Where PWC = capacity costs wood

7) PEC = (((\$ELECT * (i/(1 - (1 + i)$^{-no}$))) * (1+ (OMRO/100))) * DO)

Where PEC = capacity costs electricity

8) PGC = (((\$GAS * (i/(1 - (1 + i)$^{-no}$))) * (1 + (OMRO/100))) * DO)

Where PGC = capacity costs gas

9) APC_t = ((((SATG * (1 + (SATGG/100))$^{t-1}$) * PGC) + ((SATE * (1 + (SATEG/100))$^{t-1}$) * PEC)) * (1/((SATG * (1 + (SATGG/100))$^{t-1}$) + (SATE * (1 + (SATEG/100))$^{t-1}$))))

Where APC = average capacity costs gas and electricity

10) $PWCA_t$ = (PWC * ((BTUR * (1 + (BTURG/100))$^{t-1}$)/WMAX))

Where PWCA = PWC adjusted to maximum stove capacity

11) TCW_t = ($PWCA_t$ + (PW_t * (BTUR * (1 + (BTURG/100))$^{t-1}$)))

Where TCW_t = total costs wood

12) TCO_t = (APC_t + (PO_t * (BTUR * (1 + (BTURG/100))$^{t-1}$)))

Where TCO_t = total costs other fuels (i.e., gas and electricity)

13) $AFCS_t$ = (TCO_t - TCW_t)

Where $AFCS_t$ = average fuel cost savings

14) $SATW_t$ = (SATW + (C * ($AFSC_t$) * (1 - (1 - GAMMA)$^{t-1}$)))

Where $SATW_t$ = saturation rate wood

15) HSW_t = (($SATW_t$ * HS_t) * (1 + (CI + PI + WBE)))

Where HSW_t = households with wood heat adjusted for inconvenience, pollution, and woodburner ethic

16) For t = 2,....,n

$$Q_t = Q + \sum_{j=2}^{t} Q * \left(\left(\frac{PW_j}{PW_{j-1}} - 1\right) * EW * (1 - (1 - GAMMA)^{t-(j-1)}) + \left(\frac{PO_j}{PO_{j-1}} - 1\right) * EO * (1 - (1 - GAMMA)^{t-(j-1)})\right)$$

Where Q_t = new quantity (wood use per household) after change in relative energy prices

GAMMA < 1 means delayed reaction (i.e., short-run elasticity)
GAMMA = 1 means instantaneous reaction (i.e., long-run elasticity)

17) $TWU_t = ((HSW_t * Q_t) * (1 + (CI + PI + WBE)))$

Where TWU = total wood use adjusted for convenience, pollution, and woodburner ethic

18) $THL_t = (HS_t * (BTUR * (1 + (BTURG/100))^{t-1}))$

Where THL = total heat load

19) $TED_t = (TWU_t * (BTUW * (EW * (1 + (EWG/100))^{t-1})))$

Where TED = total energy displacement wood

20) $WEU_t = (TED_t/THL_t)$

Where WEU = wood energy use as a fraction of total home heating requirement

E. Behavioral Equations

Of the 20 algorithms listed in the previous section, most are simple accounting equations which project the number of households, energy and capacity costs, fuel cost savings, and so forth. Four equations (14 through 17), however, are particularly important and require additional explanation.

Equation 14 solves for the change in woodburner saturation that is associated with a change in average fuel cost savings. Several explicit assumptions are embodied in the equation and include: 1) the initial wood saturation rate, 2) the maximum saturation rate, and 3) the speed of adjustment (in the saturation rate) to a change in fuel cost savings.

The initial saturation rate (SATW) is 0.50 and is derived on the basis of the general public survey discussed in Chapter III. The reader should note that the original saturation rate (0.50) represents both primary and secondary wood heat; that is, simply the fraction of people with some form of woodburning device. As average fuel cost savings (AFCS)

from wood increase, the saturation rate also increases by a proportionate amount (C). For example, if C were 0.0002 and AFCS increased to $1000, then saturation would equal:

$$\text{Saturation} = 0.50 + (0.0002 * 1000) = 0.70$$

However, the reaction to a change in fuel cost savings may not be instantaneous. The GAMMA term in equation 14 allows for a delayed effect on saturation. For example, if GAMMA were 0.25, then by the end of the fifth year saturation would be 0.65, as shown below:

$$\text{Saturation Fifth Year} = (.5 + ((.0002 * 1000) * (1 - (1 - .25)^5))) = .65$$

The GAMMA term, also found in equation 16, simply allows the model user to vary household reaction time. If GAMMA equals one, the reaction is instantaneous. When GAMMA is less than one, the price response reaction is delayed.

Equation 15 provides the user with the ability to simulate changes in saturation associated with noneconomic influences; that is, the cost of inconvenience (CI), pollution impact (PI), or the woodburner ethic (WBE). CI and PI are assumed to be negative influences, while WBE is a positive influence. If the sum of the negative influences (CI + PI) is greater than the positive influence (WBE), then number of households with woodburners will decline. For example, if CI were -0.5, PI were -0.6, and WBE were 1.0, the number of households with wood heat would decline by ten percent. This same effect is also present in equation 17, which projects total wood use. These subjective parameters (CI, PI, WBE) were originally included in the simulation since they were part of the WOODSTOV/2 model which served as the basis for the WEST model (see Appendix D). An approach for estimating these parameters has not been developed.

Equation 16 simulates the change in wood use per household that is associated with either a change in the price of wood or the price of other fuels. All changes are computed relative to the beginning year wood use level, in the present case 2.6 cords per year as defined by the general public survey. The equation embodies five general components: 1) the change in the price of wood ($PW_t/PW_{t-1} - 1$), 2) the elasticity of wood (EW), 3) the change in the price of other fuels ($PO_t/PO_{t-1} - 1$), 4) the cross elasticity of other fuels (EO), and 5) a price response lag term GAMMA.

The GAMMA term is used to reflect the difference between short-and long-run elasticity. In other words, when GAMMA equals one both the direct price elasticity of wood (EW) and the cross elasticity of other fuels (EO) are equal to their long-run values. When GAMMA is less than one, for example .25, the elasticity coefficients are 76 percent adjusted by the end of year 5.

The price effects (over time) for different forecast years are summed to yield the total effect on wood consumption per household. In other words, the effect of either a change in wood price or other fuel prices increases over time, converging to the long-term elasticity values. The price effect in year 2 and so forth may be different than in year 1 since wood and other fuel cost increases may be different. The total effect of the price change in year 2, 3, and so forth also increases over time as the elasticity coefficients converge toward their long-term values. To fully understand the arithmetic of equation 16, the reader may wish to review the computer code in Appendix C or an example model run in Appendix E (medium scenario, add on matrix output).

F. Parameter Values

As indicated earlier, the DNRC forecasting focus was on wood fuel use within the MPC electric service area. As a result, the variable and/or constant input values shown in Table 17 are designed to reflect conditions for the MPC grid.

A range of parameter values (low, medium, and high) are provided for those variables that appear to be the most likely candidates for simulation and sensitivity analysis. Those values that seem to be more certain (e.g., current number of households, current saturation) are treated as constants. Those values, however, can also be modified if the user choses to do so.

In order to eliminate the range of simulation combinations, not all the variables shown in Table 17 are screen control input values. In other words, even though all values (constants or variables) may be modified, only 17 parameters appear as screen control simulation inputs in the model. It is believed that the following variables represent the most significant influences on wood consumption.

1) Base Year
2) Households
3) Household Growth
4) Price Wood
5) Price Wood Growth
6) Price Gas
7) Price Gas Growth
8) Cords Per Household
9) Gas Saturation
10) Electric Saturation
11) Wood Saturation
12) Wood Stove Cost
13) Electric Furnace Cost
14) Gas Furnace Cost
15) Saturation Conversion Rate
16) Price of Electricity
17) Discount Rate (Apple II version only)

TABLE 17

SIMULATION MODEL INPUT BOUNDS[1]
(DOLLAR VALUES IN REAL TERMS/$1984)

Variable		Low	Medium	High
HS -	Initial Number of Households	N/A	200,000	N/A
HSG -	Household Growth Rate	2.0%	2.3%	2.6%
BTUR -	Average BTU Requirement Per House	N/A	62	N/A
BTURG -	Change in Heat Load Requirement	N/A	-2.5%	N/A
WE -	Conversion Efficiency Wood	N/A	0.40	N/A
EWG -	Growth Rate in Efficiency Wood	N/A	1.0%	N/A
BTUW -	Heat Output Per Cord (Million BTUs)	N/A	19	N/A
PW -	Price Wood ($ Cord)	$30	$35	$40
PWG -	Price Wood Growth (Annual % Rate)	0.0%	0.0%	3.0%
EG -	Conversion Efficiency Gas	N/A	0.60	N/A
EGG -	Growth Rate in Efficiency Gas	N/A	1.0%	N/A
PG -	Price Gas ($ Million BTU)	N/A	$4.35	N/A
PGG -	Price Gas Growth (Annual % Rate)	2.2%	2.7%	3.2%

PE - Price Electricity (Annual $/MM BTU)	Low	Medium	High
1984	$12.33	$12.33	$12.33
1985	$13.55	$17.64	$19.66
1986	$14.77	$19.66	$19.66
1987	$16.00	$18.87	$19.66
1988	$17.22	$17.99	$19.66
1989	$18.44	$17.36	$19.66
1990	$19.66	$17.37	$19.66
1991	$19.66	$16.84	$19.66
1992	$19.66	$16.35	$19.66
1993	$19.66	$18.12	$19.66
1994	$19.66	$16.76	$19.66
1995	$19.66	$16.35	$19.66

Q -	Cords Per Household With Woodburning Device (Initial)	N/A	2.6	N/A
EW -	Elasticity Wood	-0.25	-0.5	-0.75
EO -	Elasticity Other Fuels	0.25	0.5	1.0
GAMMA -	Time Response Adjustment	0.1	0.25	0.50
n -	Number of Years in Forecast	N/A	13	N/A

TABLE 17 (Cont'd)

	Variable	Low	Medium	High
CI -	Cost Inconvenience (%)	N/A	-0.5	N/A
PI -	Pollution Impact (%)	N/A	-0.5	N/A
WBE -	Woodburner Ethic (%)	N/A	+1.0	N/A
SATG -	Saturation Rate Gas (Initial)	N/A	0.66	N/A
SATE -	Saturation Rate Electricity (Initial)	N/A	0.15	N/A
SATW -	Saturation Rate Wood (Initial)[2]	N/A	0.50	N/A
SATGG -	Saturation Gas Growth (Annual % Change)	0.5%	0.9%	1.4%
SATEG -	Saturation Electricity Growth (Annual % Change)	0.9%	1.4%	1.8%
$STOVE -	Price Wood Stove ($)	N/A	$1,000	N/A
$ELECT -	Price Electric Heat ($)	N/A	$750	N/A
$GAS -	Price Gas Heat (%)	N/A	$2,500	N/A
i -	Interest Rate (%)	N/A	6.0%	N/A
nw -	Term Wood (Years)	N/A	10	N/A
no -	Term Other (Years)	N/A	20	N/A
OMRW -	Operation, Maintenance, Repair Wood (% of Annual Capacity Costs)	36%	48%	60%
OMRO -	Operation, Maintenance, Repair Other (% of Annual Capacity Costs)	10%	20%	30%
DW -	Wood Cost Perception Adjustment	N/A	1	N/A
DO -	Other Cost Perception Adjustment	N/A	1	N/A
WMAX -	Maximum Output Per Stove (Millions of BTUs Per Year)	20	30	40
C -	Wood Conversion Coefficient	0.0001	0.0002	0.0003
DUM -	Dummy Wood Cost ($ Per Million BTUs)	N/A	$0	N/A

Note: N/A = Not Applicable

[1] The low or high input bound values do not necessarily constitute the low or high scenarios. For example, the high bound electric prices yield the low scenario projection for wood use. See Appendix E for greater detail.

[2] Saturation of wood includes both primary and secondary heat.

Additionally, within the simulation model, the medium scenario variable values shown in Table 17 are set as default values. That is, unless modified and "saved," the system values will return to the original default value when the model is started again.

A justification for the input values is provided in the following paragraphs. Some of the values are intuitive in nature, while others can be referenced to specific studies or data sources.

Households (HS): The number of households was estimated on the basis of reported MPC residential customer data. The 1984 value was extrapolated from the 1982 value, assuming constant growth (comparable to last decade).

Household Growth (HSG): During the past decade (1970-80), the annual rate of change in household growth at the state level was 2.7 percent per year as compared to 2.6 percent for MPC residential customer growth. The low value (2.0 percent) assumes a slowdown in general economic activity and no inmigration, while the high value (2.6 percent) assumes a continuation of the 1970-80 growth rate. The medium scenario at 2.3 percent is in between the low and high values.

BTU Requirement Per Household (BTUR): This value (62 million BTUs per year) was supplied by the Energy Division, DNRC and represents a typical house. Comparable sized new houses may require as little as half that amount.

BTU Requirement Growth (BTURG): DOE residential energy use data suggest that total BTUs per household declined at an average rate of 0.6 percent per year between 1970 and 1980.[12] Between 1978 and 1981, total

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[12] U.S. Department of Energy, Energy Information Administration, no date, "State Energy Data Report, 1960-81," DOE/EIA-0214(81).

residential use fell from 64 trillion BTUs to 55 trillion BTUs, primarily because of climatic variation. The value (constant) used in the simulation system was set at a constant rate of decline at -2.5 percent per year, much larger than the rate of decline during the past decade. The implication is that heat load per household would decline 25 percent between 1984 and 1995, the end of the forecast period. Furthermore, the heat requirement per average household would decrease from 62 million BTUs in 1984 to 47 million BTUs by 1995. In other words, this scenario requires a comparatively high level of conservation. Dr. Terry Morland of the Northwest Power Planning Council estimates that the annual rate of decline will be on the order of 2.8 percent per year for the Pacific Northwest. In any event, this parameter does not significantly influence wood consumption within the model. For example, with no decline in energy requirement per household, by 1995 the wood forecast value would be only 0.3 percent higher than the medium scenario.

Efficiency Wood (WE): In discussions with the DNRC, an assumption was made that the average efficiency of woodburning devices was 40 percent. Although the distribution of stoves and fireplaces (see Appendix A, Q-16) is consistent with this estimate, this value may be somewhat high.

Efficiency Wood Growth (EWG): This value was assumed to be one percent per year. Furthermore, it assumes that 75 percent of new homes install wood stoves or fireplaces (60 percent and 40 percent, respectively); maximum stove efficiency is 70 percent; current stove efficiency is 50 percent; maximum fireplace efficiency is 15 percent; and current fireplace efficiency is 7.5 percent.

BTUs Per Cord of Wood (BTUW): This was a constant value of 19 million BTUs per cord based on the estimated type of wood burned in Montana (assuming a specific gravity of 0.44).

Price Wood (PW): The medium scenario value assumed that 60 percent of woodburners cut wood and 40 percent buy wood at $25 and $50, respectively. This value is derived from the reported perceived costs by woodburners and nonwoodburners (see Appendix A).

Price Wood Growth (PWG): A review of Sunday newspapers (1970, 1975 and 1980) during August through November for Montana's six largest urban areas suggests that the real price of wood has been constant. Therefore, the low and medium values are assumed to be 0.0 percent growth per year and the high value is assumed to be 3.0 percent.

Efficiency Gas (EG): The DNRC provided this value of 60 percent.

Efficiency Gas Growth (EGG): This was assumed to be one percent per year.

Price Gas (PG): This price was an estimate of the current average MPC gas price--$4.35 per million BTUs, which includes the winter rate reductions.

Price Gas Growth (PGG): This value was derived from the MPC forecasts of low, medium, and high prices.[13]

Price Electricity (PE): The medium scenario is based on MPC projections which assumed that both Colstrip units would be rate-based as construction was completed. The low scenario assumed that both units were phased into rate base over the next six years. The high scenario

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[13] Montana Power Company, "Electrical Forecast Model", unpublished computer listing, January 1984.

assumed that both units were immediately rate-based with no reduction in long-term real prices. The medium scenario was developed from the MPC load and price forecasts (January 1984).

Wood Use Per Household (O): The estimated cords per household value was 2.6 cords for 1984 woodburners averaged over primary and secondary users. This estimate was derived from the general public wood fuel use telephone survey.

Elasticity Wood (EW): Wood elasticity (long-run) coefficients were assumed to be comparable to the range of electric estimates throughout the Northwest. The medium scenario was 0.5, whereas the range was from 0.25 to 0.75 as shown below:

	Electric Residential	
Source	Short-Term	Long-Term
MPC	-.049	-.711
PGE	-.10	-.30
Regional Power Council	-.09	-.40
BPA (1982)	N/A	-.3 to -.9
PNUCC (1980)	-.06	-.25

Long-term electrical and gas elasticity coefficients estimated by ECO were also in the 0.3 to 0.5 range for both state cross-section time series (1970, 1975, and 1980) and MPC time series data (1970-82).

Elasticity Other (EO): Analysis of the effect of competing energy prices on wood use (Chapter IV, Section B) suggests an unusually high cross elasticity coefficient--0.4 to over unity. Theoretically, the cross elasticity absolute value must be equal to or less than the direct absolute elasticity value. The medium scenario assumed that both absolute values were 0.5; the high scenario assumed that the direct and cross values were -.25 and 1, which is in violation of theory. The low scenario assumed that the direct coefficient was -0.75 and the cross value was 0.25.

Time Response Adjustment (GAMMA): The medium scenario (GAMMA = 0.25) assumed that 94 percent of the price response occurs within 10 years; that is, $(1 - (1 - GAMMA)^n) = 0.94$ when GAMMA = 0.25 and n = 10. The low scenario (GAMMA = 0.1) assumed that 65 percent of the price response occurs within 10 years. The high scenario (GAMMA = 0.5) assumed that 100 percent of the price effect occurs within 10 years.

Number of Years (n): Number of years in forecast.

Variable	Value
Cost Inconvenience (CI):	-0.5
Pollution Impact (PI):	-0.5
Woodburner Ethic (WBE):	1.0

It was not possible to quantify these influences from the survey data. As a result, the values were set in such a way as to cancel out the positive and negative attitudes toward wood.

Saturation Gas (SATG): 66 percent as derived from the 1982 MPC end use survey.

Saturation Electricity (SATE): 15 percent as derived from the 1982 MPC end use survey.

Saturation Wood (SATW): This was assumed to be 50 percent (see Table 1, Chapter II). This represents both primary and secondary wood heat.

Saturation Gas Growth (SATGG): The medium growth rate assumed that 40 percent of new homes have gas heat. The low and high penetration rates were 61 and 22 percent, respectively.

Saturation Electric Growth (SATEG): The medium growth rate assumed that 60 percent of new homes have electric heat. The low and high

penetration rates were 39 and 78 percent, respectively. According to the MPC, current penetration rates for primary electric heating are closer to 50 percent. The medium scenario assumed a higher level (60 percent) of primary and secondary electric heat since it was believed that 60 percent of future population growth will occur outside the MPC gas network.

Stove Capacity Costs ($STOVE): The average installation cost of a stove as reported in the general public wood use telephone survey (see Appendix A, Q-19) was $750. This value may reflect historical prices, but not current prices. On the basis of conversations with wood stove dealers, the current average price is approximately of $1,250 per unit. These two figures (estimates of general public and wood stove dealers) were averaged ($1,000) for the medium scenario.

Electric Capacity Costs ($ELECT): The medium scenario value was set at $750 per household.[14]

Gas Capacity Costs ($GAS): The medium scenario value was set at $2,500 per household.[15]

Real Interest Rate (i): This was assumed to be six percent.

Term Wood (nw): The life expectancy for a wood stove was assumed to be 10 years.

Term Other (no): The life expectancy for gas and electric systems was assumed to be 20 years.

Operation Maintenance and Repair Cost Wood (OMRW): This was expressed as a percent of annual capacity costs. In the medium scenario,

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[14] Ken Coram, Northwest Regional Power Planning Council, personal communication, July 1984.

[15] Danny Parker, Energy Division, Montana Department of Natural Resources and Conservation, personal communication, July 1984.

the annual rate was 48 percent per year; the actual value was $96. The low and high values were $72 and $120, respectively. The medium value per stove included $40 annually for sweeping/cleaning and $56 annually for relining and miscellaneous repairs and parts.

Operation, Maintenance and Repair Cost Other (OMRO): This was expressed as a percent of annual capacity costs. The rate for the medium scenario was 20 percent, or $40 annually. The low and high values were $23 and $65, respectively.

Variable	Value
Wood Cost Perception Adjustment (DW)	1
Other Cost Perception Adjustment (DO)	1

Wood and other capacity costs were amortized. In other words, neither the capacity costs of wood nor other heating systems was regarded as a sunk cost. Model users may wish to vary these inputs. The above two parameters (DW and DO) were included to allow the user to simulate the impact of differential perceptions of capacity costs.

Maximum Stove Output Per Stove (WMAX): The medium scenario assumed an average output of 20,000 BTUs per unit, a 10-hour burning day, and a 150-day woodburning season. The medium annual value was 30 million BTUs per unit. The low and high values were 20 and 40 million BTUs per year, respectively.

Saturation Conversion Function (C): This parameter links the average fuel cost savings and wood saturation rates. In the medium scenario, saturation was assumed to rise from 50 percent to 70 percent if average fuel cost savings rose to $1,000 per year. The low scenario assumed that saturation would rise to 60 percent when average fuel cost

savings rose to $1,000 per year. The high scenario assumed that saturation would rise to 80 percent when average fuel cost savings rose to $1,000 per year. The medium value for this parameter was 0.0002. The high and low values were 0.0003 and 0.0001, respectively. These are assumed values given the current wood saturation rate and the maximum levels as previously stated.

V. WOOD FUEL USE PROJECTIONS

A. Overview

This section explores the range of probable future wood fuel use levels within the MPC service area. At the time the contract was let, the DNRC was interested in this area because of the proposed Salem plant. A variety of projections utilizing different sets of assumptions and modeling techniques are provided. First, the WEST wood use model is run under high, low, and medium input parameter assumptions as developed in Chapter IV. A second projection, using the WOODSTOV/2 system by Norman L. Marshall, is included for comparison.[16] Sensitivity tests to different input assumptions are also made. The final section reviews the most likely future for wood use and explores the implications of this future for energy planning in Montana.

B. Historical MPC Wood Use Estimates

The DOE residential wood use series for Montana was used to estimate wood use within the MPC service area. The estimates and the calculation procedure are provided in Table 18. As can be seen, simple population ratios were used to develop a time series for the MPC. Even though the DOE estimates are uncertain, they should be accurate enough to establish general patterns in use over time. These historical data are also plotted in Figure 4.

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[16] Norman L. Marshall, "The Dynamics of Residential Wood-Energy Use in New England 1970-2000," Thayer School of Engineering, Dartmouth College, October 1981.

TABLE 18

MPC RESIDENTIAL WOOD USE

Year	DOE Residential Wood Use[1] (Cords)	Montana Population[2]	MPC Area* Population[3]	MPC Residential Estimated Wood Use[4]
1960	220,800	674,767	531,300	174,000
1965	169,600	684,588	563,000	139,000
1970	129,600	694,409	549,200	102,000
1975	142,400	749,000	594,800	113,000
1980	302,400	786,690	627,200	241,000

Sources:

[1] Applied Management Sciences, "Estimates of U.S. Wood Energy Consumption from 1949 to 1981," 1982, prepared for U.S. Department of Energy.

[2] U.S. Department of Commerce, Bureau of the Census (1965 figure represents an average of 1960 and 1970 data).

[3] Montana Power Company, Butte, Montana

[4] Derived from preceeding data by simple population ratios.

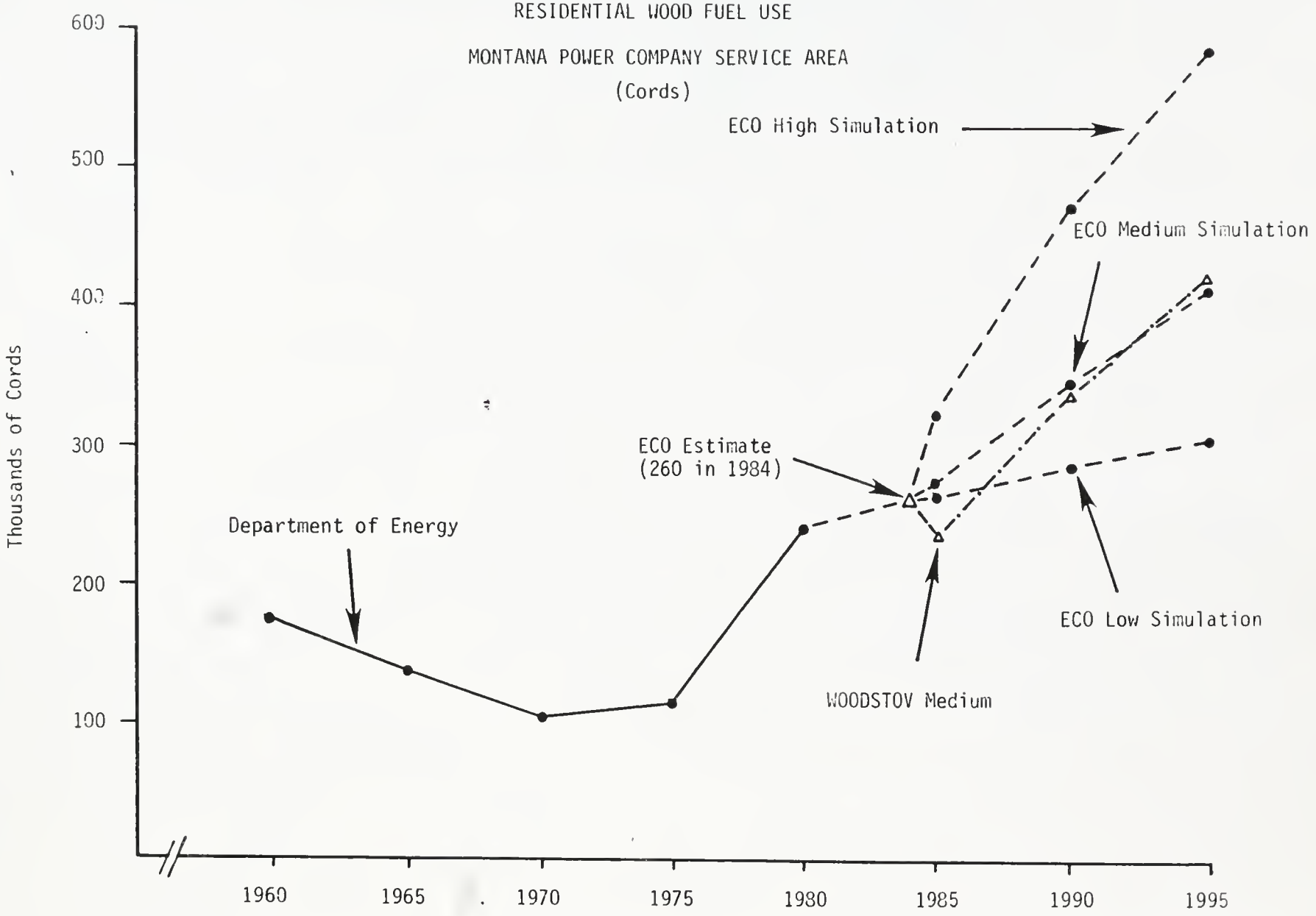
* Note: Population level includes the number of individuals in counties served by MPC, not the number of actual MPC customers.

FIGURE 4

RESIDENTIAL WOOD FUEL USE

MONTANA POWER COMPANY SERVICE AREA

(Cords)



Source: ECO Northwest Ltd., Helena, Montana.

Assuming the DOE/MPC estimates are valid, the series indicates that wood use steadily declined from 1960 until the mid 1970s and then sharply increased, presumably because of natural gas price increases. Between 1972 and 1982, residential gas price (MPC real price) increased 114 percent and household use levels of gas declined by 29 percent.

Although the MPC residential end use survey does not explicitly report total residential wood fuel use, the survey does estimate primary/secondary wood saturation at 51 percent, four percent higher than the ECO survey (see Appendix A, Q-4) at 47 percent. By the same token, wood use estimates per MPC household (for households with some type of wood heat) reveal that primary wood users consume 5.3 cords per year and that secondary woodburners use 2.5 cords per year.[17] Given the 51 percent saturation rate (total) and the primary wood saturation rate of 10.9 percent, the survey implies that total wood use in 1982 (given 195,838 residential customers) was approximately 309,600 cords. This is significantly higher than the 1984 ECO estimate of 260,000 cords. The ECO estimate assumes a total saturation rate (primary and secondary) of 50 percent, 200,000 total households, and an average use level of 2.6 cords per year per household with wood heat. The ECO use of a 50 percent saturation rate rather than the 47 percent rate as reported in the general public survey is purely judgmental. In any event, the actual MPC use level may be higher than the 1984 ECO estimate suggests.[18]

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[17] Montana Power Company "1982 MPC Residential Survey Executive Summary," 1982, p. 9-10.

[18] The discrepancy between the ECO and MPC survey may be the result of MPC's use of open-ended questions versus ECO's use of interval ranges.

C. Projected MPC Wood Use Levels

In view of the lack of either a solid time series or completely dependable base year estimate, long-term projections embody a high degree of uncertainty. Consequently, discretion is advised when attempting to analyze implications of the simulations shown in Figure 4 and Table 19.

The three WEST model simulations (high, medium, and low) contained in Table 19 represent the outputs generated by the various input assumptions found in Table 17 (Chapter IV). As the reader will recall, the input assumptions were developed in such a way as to provide maximum reasonable variation between the high and low values. Conceptually, this approach is similar to the Northwest Regional Power Planning Council's planning scenario, where no formal probability is assigned to any particular point forecast value. Both input values and annual output values for each WEST model scenario are shown in Appendix E.

The WOODSTOV/2 medium simulation values shown in Table 19 were developed on the basis of the WOODSTOV/2 model by Norman Marshall in 1981. William Johnston, University of Montana MA candidate in Economics, was responsible for rewriting WOODSTOV/2 in BASIC (as opposed to DYNAMO). All common input variables between WOODSTOV/2 and the WEST variation were set to the medium scenario values contained in Table 17. Those WOODSTOV/2 parameters which were not in common with the WEST model were set equal to the original Marshall values with two exceptions. First, the inconvenience costs in WOODSTOV/2 were eliminated, and second, the household heating requirements were assumed by Johnston to be 87.5 million BTUs in 1984 and

TABLE 19

SIMULATION RUNS
THOUSANDS OF CORDS

Year	WEST			WOODSTOV/2
	Low	Medium	High	
1985	264	274	319	237
1990	285	342	463	337
1995	305	410	576	422
Increase 1984-95	17%	58%	122%	62%

Source: Derived from preceeding assumptions.

also allowed to decline linearly to 52.5 million BTUs in 2004. The first time WOODSTOV/2 was run (June 1984), ECO was utilizing DNRC supplied values of 100 million BTUs per year, which were later modified. When the system was run by Johnston (with the 100 million BTU requirement, Marshall's inconvenience cost as contained in WOODSTOV/2, and common WOODSTOV/2 and WEST medium values as described above), the system significantly understated wood use. For example, the 1984 value for total MPC wood use was 140,500 and 71,500 cords in 1995. When the BTU requirement was lowered to 78 million BTUs per household, the 1984 and 1995 use values were 152,500 and 74,500 cords, respectively. However, after the influence of inconvenience costs was eliminated, the WOODSTOV/2 projections shown in Table 19 (with an initial BTU requirement of 87.5 million BTUs) were plausible, but difficult to interpret given the complexity of the system. (WOODSTOV/2 is discussed in greater detail in Appendix D.)

The 1995 medium simulation values (WEST model) shown in Table 19 suggest that wood use for the MPC service area will increase from 260,000 cords in 1984 to 410,000 cords by 1995--and increase of nearly 60 percent. The WOODSTOV/2 projections are comparable. The general plausibility of these results is explored in the following sections.

A backcast test of the WEST model for the MPC area (1973-84) is found in Appendix F. This test suggests that when input parameter values are "reasonable," the simulation system is capable of producing valid projections as compared to the DOE/MPC wood use series.

D. Sensitivity Testing

The WEST simulation model projections of wood fuel consumption are clearly a function of both the structure of the system as well as the input parameters. For example, the high scenario inputs (see Figure 4) yield a 1995 projection of 576,000 cords versus the low scenario value of 305,000 cords consumed for the MPC electric service area. As previously mentioned, the wide range of input bounds is clearly responsible for the variation in projected values (see Table 17).

As with any forecast, the medium scenario is generally assumed to be more plausible than either extreme. Table 20 provides an indication of the range of variation in projections (for 1995) when all other input parameters are held constant as specified in the medium scenario of Table 17.

In the case of Table 20, the price of stove capacity is varied between $750 and $1,500, the price of wood ranges between $20 to $50 per cord, the rate of growth in real wood price ranges from 0 to 4 percent per year, and real gas prices are either 2 percent or 4 percent per year. The projections further assume that both Colstrip units are rate-based on the original schedule.[19] Given the simultaneous changes in the above parameter values, the overall projections do not, as shown in Table 20, exhibit the degree of variation that one would expect a priori. For example, the highest 1995 value was only 21 percent larger than the mean value (383,000

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[19] While this does not seem likely to occur, the 1995 medium scenario forecast with full rate-basing results in a simulated use level of 410,000 cords. On the other hand, if real electrical prices were held constant at the 1984 level throughout the entire forecast period, the 1995 use level would be just 5 percent lower than the medium scenario.

TABLE 20

SENSITIVITY TESTING
1995 TOTAL WOOD USE
(1000s of Cords)

Stove Cost		$750			$1,000			$1,500			Gas Price Change
Wood Price		$20	$35	$50	$20	$35	$50	$20	$35	$50	
Growth in Wood Price	0%	429	417	405	418	406	394	395	384	372	2%
		465	452	440	453	440	428	429	417	404	4%
	2%	395	381	367	384	371	357	363	350	336	2%
		429	415	400	418	404	389	396	382	367	4%
	4%	360	344	329	350	335	319	331	315	300	2%
		393	377	360	383	366	350	363	346	329	4%

Source: ECO Northwest, Ltd., Helena, Montana.

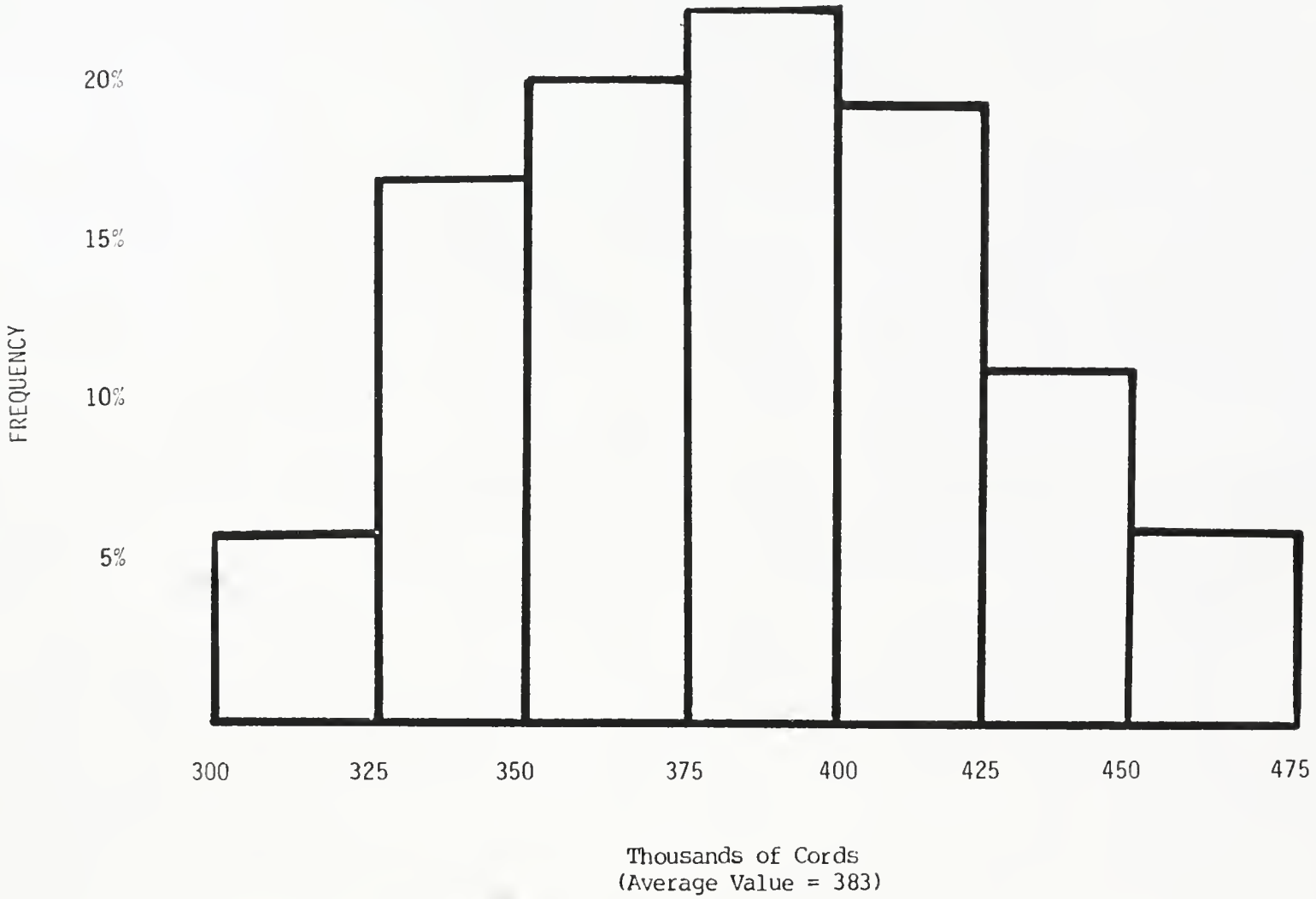
Note: Assumes ending year natural gas price of $6.97 per million BTUs in 1984 dollars versus $5.83 for the medium scenario simulation. The range in gas price changes is wider than that used by MPC in their electrical demand model to better test the sensitivity of the WEST model.

cords) while the lowest value was 22 percent lower than the mean value. The values shown in Table 20 are also plotted in Figure 5 which shows the distribution of projected values by intervals of 25,000 cords versus the frequency of occurrence. The reader is, however, cautioned not to regard the frequency of occurrence as a probability value for the projection.

The relative stability of the system may lead to a degree of confusion. As mentioned earlier, the projections seem to be somewhat insensitive to changes in individual parameters versus changing all parameters to simultaneous high or low bound values such as shown in Table 17. The tendency for system dynamics to be relatively insensitive to variation in individual parameter estimation was also noted by Marshall. This general tendency appears to be true for all "systems type" simulations of which the author is aware. This is probably the result of the number of equations and parameters involved. In other words, with few equations or parameters, a change in any particular value may result in a dramatic difference in the projection. With numerous equations and/or parameters the relative influence of any one parameter on the result is far less, due to no more than model structure. For example, in an additional sensitivity test where the medium scenario values were again used, the price sensitivity factors were set at their extreme bounds. These variables included the direct and cross elasticity coefficients and the time response term (GAMMA variable). Again, the 1995 projected value only varied $\pm$ 9 percent from the medium. If comparable changes had been made within either an econometric or potentially an end use framework, the impact on projected wood use levels would have probably been greater. This issue is discussed in the conclusions section of the present chapter.

FIGURE 5

DISTRIBUTION OF PROJECTED VALUES (1995)
CORDS (1000s)



Source: ECO Northwest, Ltd., Helena, Montana

E. Energy Implications

All projections (Figure 4) suggest that wood fuel consumption will continue to increase for the MPC service area. Nevertheless, given the unusual level of uncertainty involved in wood fuel consumption analysis and forecasting, the information embodied in the projections is more likely to be qualitative rather than quantitative in nature. Although the WEST model high and low projection series are "possible," it is the contractor's opinion that neither scenario is likely. Therefore, attention is focused on the implications of the medium scenario.

The annual model values are shown in Appendix E. The estimates, projections, and the wood fuel survey (Appendix A) suggest the following:

1) Actual fuel cost savings (AFCS) for the average household heating with wood are rather low, less than $100 per year. Average fuel cost savings, however, are expected to rise to approximately $200 per year within a decade.

2) Based on on the typical amount of time spent for cutting, hauling, and splitting firewood, and so forth, savings would be equivalent to approximately $3.00 per hour for the average household over the entire forecast period.

3) In addition to actual savings, approximately 40 percent of current woodburners consider wood cutting and gathering a form of recreation (Q-27). This recreational aspect may reduce the perceived cost of wood since cutting and gathering has a value of its own.

4) Average fuel cost savings is based on both a mixture of gas and electric heat as well as the average of primary and secondary wood heat savings. Annual fuel cost savings of total wood heat versus total electric

heat would be much higher than the average, perhaps double. In addition, it is entirely possible heating with wood as opposed to gas may result in no cost savings, contingent on the purchase or gathering costs of wood.

5) Since actual household savings is affected by the type of primary or secondary heat, the efficiency of the stove, woodburning habits, and the cost of wood itself, the average fuel cost savings parameter in the WEST model is no more than a rough approximation of household savings.

6) Few nonwoodburners (8 percent) have recently considered installing either a wood stove or fireplace (Q-5). Additionally, half of the nonwoodburners consider heating with wood too inconvenient (Q-6). If they were to install a wood stove, most would cut their own wood (Q-8). Most nonwoodburners also believe that heating with wood saves money (Q-12). Apparently, inconvenience, extra chores, and concern over pollution outweigh the perceived savings and keep current nonwoodburners from converting to wood (Q-14). It is also possible that nonwoodburners' attitude toward installing a woodstove is influenced by renter/owner patterns.

7) Even though few nonwoodburners are now considering installing a wood stove or fireplace, an increase in energy price may cause them to reconsider. The sharp increase in natural gas price during the 1970s is believed to have increased the saturation (primary and secondary) from an estimated 40 percent to 50 percent at the current time.

8) With respect to current woodburners, about 40 percent of the wood stove or fireplace installations have been made within five years (Q-17). The vast majority (over 80 percent) of woodburners believe that their stove will pay for itself within five years (Q-20 and Q-21). Roughly 60 percent currently cut their own wood, generally driving less than 60

miles round trip (Q-24 and Q-26). However, only half of those surveyed think it is less expensive to cut than to buy wood (Q-27). Furthermore, most woodburners do not anticipate changing their wood consumption levels in the near future (Q-31). Current woodburners are less likely than nonwoodburners to believe that woodburning is a major source of air pollution.

9) Although most woodburners do not anticipate changing their wood consumption levels, the sharp natural gas price increase of the 1970s is believed to have resulted in a consumption increase of approximately 40 percent per household (i.e., 1.9 cords per household in 1973 to 2.6 cords in 1984). Further price increases will probably result in higher household consumption levels.

10) Wood saturation is currently about 50 percent and is projected to increase to 55 percent by 1995. The expected change in the saturation rate is less than the change last decade when saturation was believed to increase from 40 to 50 percent (Appendix F, Table F-1).

11) Wood use per household (heating with wood) is projected to increase from 2.6 cords per year to 3.0 cords by 1995, a 14 percent increase. This increase also appears to be less than the experience of the past decade when wood use levels seemed to increase about 40 percent per household (Appendix F, Table F-1).

12) Total wood use is projected to rise from 260,000 cords currently to 410,000 cords by 1995, a 58 percent increase. Last decade, wood use appeared to more than double.

13) Wood use is currently estimated to provide about 16 percent of home heating requirements. By 1995, it is expected that nearly 30 percent of home heating requirements may be met by wood use. (This assumes no

further pollution control measures.) For comparison, a decade ago wood use was believed to account for only six percent of home heating requirements (Appendix F, Table F-1).

14) The backcast results indicate that the average wood use per all households was 0.76 cords in 1975 and 1.01 cords in 1980. For comparison, the DOE statewide estimates are 0.6 and 1.1 for 1975 and 1980, respectively.

15) Of the total increase in projected wood use between 1984 and 1995 (150,000 cords), about one-half of the increase seems to be associated with household formation. This may be the single most important factor in determining future wood use consumption, particularly since approximately one-half of new homes (on the MPC grid) have electric space heat and many of these homes also have wood stoves. The 1982 MPC end use survey results showed that one-third of the primary wood heaters use electricity as back-up heat. These newer homes are also twice as likely to heat with wood since they are constructed with wood stoves.

16) Even though the potential savings (between wood and electric space heat) appears to be over double that of the average residence (with 66 percent gas, 15 percent electric heat), the projections seem to be rather insensitive to electric rate scenarios (see Table 17, Chapter IV). For example, if there were no increases in electric rates (through the entire forecast period), the forecast of total wood consumption would be only five percent lower than the medium scenario. This result is probably related to the fact that there are still comparatively few homes with electric heat. In contrast, the sharp increase in wood use during the past decade appears to have been primarily a function of a doubling in real gas

prices and high gas primary heat saturation. If current electric saturation rates were comparable to gas rates during the 1970s, major increases in electric rates would have a major impact on wood use.

F. Conclusions and Recommendations

Although wood use consumption is expected to increase nearly 60 percent between 1984 and 1995, the rate of increase will probably be less than the experience of the past decade. The relative contribution of wood to total heating requirements is, however, expected to continue to rise, approaching nearly 30 percent of total residential heat load by 1995. These projections assume no further controls on woodburning which may not be true, particularly in the Missoula and Helena areas. Since there is no way to determine what will take place with respect to air quality regulations, potential national wood stove standards, and so forth, the projections should be regarded as an upper bound on development. Furthermore, even though wood supply constraints may not exist today, the 60 percent forecast increase in wood use may create supply problems or at least potentially drive wood prices up. If these higher prices were fed back into the WEST model they would reduce consumption. By 1995, for example, residential wood fuel gathering relative to the reported commercial harvest (an average 1,250 million board feet) could represent up to 25 percent of the total, up from an estimated 17 percent today.

In order to monitor future wood use levels, it is recommended that the DNRC periodically (every two years) survey wood use. In addition, it is recommended that the DNRC develop city level projections to test the amount of pollution generated and, explore in conjunction with local health planning agencies reasonable pollution bounds and how those bounds may affect the fuel wood projections.

While there is considerable uncertainty over the projections, the WEST model appears to be generating plausible trends. Given the lack of a fully reliable historical wood use series, however, the high level of uncertainty cannot be reduced regardless of model structure.

Although simulation model refinement, primarily disaggregation into primary/secondary wood heat components, fuel-specific savings functions, and a stove/fireplace sector, may improve the conceptual appeal of the system, it is doubtful that such changes would significantly reduce forecast error. One change, however, may be worth experimenting with. At the local level, it may be possible to estimate pollution levels associated with increased wood use. If this is possible, the projection could be constrained to acceptable (or regulated) pollution levels. In Missoula, the combination of both regulations and public attitudes toward pollution appears to have slowed the growth in wood consumption. While it may be impossible to determine the influence of public attitudes on wood use, the pollution constraint impact of regulation may be quantifiable.

With regard to model improvement utilizing an econometric approach, the data limitations discussed in Chapter IV (Section B) probably preclude additional refinement. Without accurate wood price information it is very difficult to forecast wood use. Furthermore, the wood price series which was developed during the course of this study was found to not be a statistically significant factor affecting wood use. Other problems such as electrical price not entering the equation (as a significant influence) when gas price was highly influential make traditional econometric specification and forecasts generally impractical when trying to simulate the wood use impacts of electrical rate increases.

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APPENDIX A

GENERAL PUBLIC SURVEY
FREQUENCY DISTRIBUTIONS

RESPONSE OF
DNRC WOOD FUEL USE TELEPHONE SURVEY

INTRODUCTION:
Hello. My name is _____ and I'm calling for the Montana Department of Natural Resources and Conservation. We are conducting a statewide survey of residential firewood use. Your phone number was randomly selected by a computer. Could I take a few minutes of your time to ask some questions about your home heating needs? All your answers will be kept confidential.

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-1	What is the primary type of fuel that you use to heat your home?				
1)	GAS	345	57.2	225	58.1
2)	ELECTRICITY	97	16.1	90	23.3
3)	PROPANE	19	3.2	6	1.6
4)	FUEL OIL	23	3.8	6	1.6
5)	WOOD	102	16.9	50	12.9
6)	COAL	6	1.0	4	1.0
7)	OTHER: SPECIFY	9	1.5	5	1.3
9)	DON'T KNOW/REFUSED	2	0.3	1	0.3
Q-2	From whom do you buy your primary heating fuel?				
1)	MONTANA POWER COMPANY	223	37.0	183	47.3
2)	PACIFIC POWER AND LIGHT	9	1.5	4	1.0
3)	MONTANA-DAKOTA UTILITY	120	19.9	67	17.3
4)	RURAL COOPERATIVE	12	2.0	5	1.3
5)	GREAT FALLS GAS	53	8.8	31	8.0
6)	OTHER: SPECIFY	172	28.5	88	22.7
9)	DON'T KNOW/REFUSED	14	2.3	9	2.3

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-3	Do you own or rent your home?				
	1) OWN	459	76.1	288	74.4
	2) RENT	143	23.7	98	25.3
	9) DON'T KNOW/REFUSED	1	0.2	1	0.3
Q-4	Do you have any workable wood stoves or wood burning fireplaces in your home?				
	1) YES - Skip to Q-16	281	46.6	183	47.3
	2) NO	322	53.4	204	52.7
Q-5	Have you recently considered installing either a wood stove or a fireplace?				
	1) YES - Skip to Q-7	25	7.8	15	7.4
	2) NO	297	92.2	189	92.6

Q-6 I am going to read a few statements that have been made about heating with wood, and I would like you to tell me whether you agree (1) or disagree (2) with these statements.

	STATE						MPC					
	Agree		Disagree		Don't Know/ Refused		Agree		Disagree		Don't Know/ Refused	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) HEATING WITH WOOD IS TOO INCONVENIENT	149	50.2	127	42.8	21	7.1	95	50.3	79	41.8	15	7.9
2) HEATING WITH WOOD CAUSES EXTRA HOUSECLEANING CHORES	213	71.7	68	22.9	16	5.4	137	72.5	40	21.2	12	6.3
3) WOODBURNING IS A MAJOR SOURCE OF AIR POLLUTION	171	57.6	107	36.0	19	6.4	113	59.8	66	34.9	10	5.3

Skip to Q-15

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-7	If you did install a wood stove or fireplace, what type would you install?				
	1) FIREPLACE	0	0.0	0	0.0
	2) FIREPLACE WITH HEATALATOR	1	4.0	1	6.7
	3) WOOD STOVE OR FIRE-PLACE WITH INSERT	18	72.0	10	66.7
	4) BOTH FIREPLACE AND WOOD STOVE	2	8.0	0	0.0
	9) DON'T KNOW/REFUSED	4	16.0	4	26.7
Q-8	If you did install a wood stove or fireplace, do you think you would cut your own wood?				
	1) YES	20	80.0	14	93.3
	2) NO - Skip to Q-10	5	20.0	1	6.7
Q-9	If you cut the wood yourself, what do you think a cord would cost?				
	1) LESS THAN $20 PER CORD	8	40.0	6	42.9
	2) $20 TO $30	3	15.0	1	7.1
	3) $31 TO $50	2	10.0	1	7.1
	4) MORE THAN $50	1	5.0	1	7.1
	9) DON'T KNOW/REFUSED	6	30.0	5	35.7

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-10	What do you think it costs to buy a cord of wood?				
1)	LESS THAN $40 PER CORD	2	8.0	1	6.7
2)	$40 TO $50	6	24.0	2	13.3
3)	$51 TO $60	6	24.0	3	20.0
4)	$61 TO $75	3	12.0	2	13.3
5)	MORE THAN $75	5	20.0	5	33.3
9)	DON'T KNOW/REFUSED	3	12.0	2	13.3
Q-11	What do you think it would cost to purchase and install a wood stove or fireplace in your home?				
1)	LESS THAN $500	3	12.0	1	6.7
2)	$500 TO $900	7	28.0	4	26.7
3)	$901 TO $1300	9	36.0	5	33.3
4)	MORE THAN $1300	5	20.0	4	26.7
9)	DON'T KNOW/REFUSED	1	4.0	1	6.7
Q-12	Do you believe that heating with wood is cheaper than heating with gas, electricity, fuel oil, or propane?				
1)	YES	19	76.0	12	80.0
2)	NO - Skip to Q-14	4	16.0	1	6.7
9)	DON'T KNOW/REFUSED	2	8.0	2	13.3

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-13	In your opinion, how much cheaper is it to heat with wood than to heat with gas, electricity, fuel oil, or propane?				
1)	LESS THAN $25 PER MONTH	5	26.3	3	25.0
2)	$25 TO $50 PER MONTH	6	31.6	4	33.3
3)	$51 TO $75 PER MONTH	3	15.8	3	25.0
4)	MORE THAN $75 PER MONTH	2	10.5	1	8.3
9)	DON'T KNOW/REFUSED	3	15.8	1	8.3

Q-14 I am going to read a few statements that have been made about heating with wood, and I would like you to tell me whether you agree (1) or disagree (2) with these statements.

	STATE				MPC			
	Agree		Disagree		Agree		Disagree	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) HEATING WITH WOOD IS TOO INCONVENIENT	7	28.0	18	72.0	3	20.0	12	80.0
2) HEATING WITH WOOD CAUSES EXTRA HOUSECLEANING CHORES	22	88.0	3	12.0	12	80.0	3	20.0
3) WOODBURNING IS A MAJOR SOURCE OF AIR POLLUTION	18	72.0	7	28.0	11	73.3	4	26.7
4) BEFORE I WOULD INSTALL A WOOD STOVE OR FIREPLACE, FIREWOOD WOULD HAVE TO BE EASIER TO GATHER	5	20.0	20	80.0	2	13.3	13	86.7
5) WOOD COSTS WOULD HAVE TO GO DOWN BEFORE I WOULD INSTALL A WOOD STOVE OR FIREPLACE	2	8.0	23	92.0	1	6.7	14	93.3
6) THE COST OF A WOOD STOVE OR FIREPLACE WOULD HAVE TO GO DOWN BEFORE I WOULD INSTALL ONE	5	20.0	20	80.0	5	33.3	10	66.7
7) BEFORE I WOULD INSTALL A WOOD STOVE OR FIREPLACE, THEY WOULD NEED TO BE LESS POLLUTING	11	44.0	14	56.0	8	53.3	7	46.7

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-15	Approximately when was your home built?				
1)	BEFORE 1940	64	19.9	34	16.7
2)	1940 TO 1949	31	9.6	25	12.3
3)	1950 TO 1959	44	13.7	26	12.7
4)	1960 TO 1969	40	12.4	23	11.3
5)	1970 TO 1974	33	10.2	20	9.8
6)	1975 TO 1978	19	5.9	15	7.4
7)	1979 OR LATER	34	10.6	22	10.8
9)	DON'T KNOW/REFUSED	57	17.7	39	19.1

END SURVEY FOR NON WOODBURNERS. THANK YOU VERY MUCH FOR YOUR COOPERATION. GOOD-BYE.

I WOULD LIKE TO ASK YOU A FEW QUESTIONS ABOUT HEATING WITH WOOD. THE ANSWERS THAT YOU GIVE SHOULD ONLY BE CONCERNED WITH YOUR WORKABLE FIREPLACE OR STOVE.

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-16	How many fireplaces, wood stoves, or fireplaces with stove inserts do you have in your home?				
	A) FIREPLACES				
	0) NONE	174	61.9	103	56.3
	1) ONE	90	32.0	66	36.1
	2) TWO	16	5.7	13	7.1
	3) THREE	1	0.4	1	0.5
	4) MORE THAN THREE	0	0.0	0	0.0
	B) WOOD STOVES OR FIREPLACES WITH STOVE INSERT				
	0) NONE	83	29.5	67	36.6
	1) ONE	175	62.3	102	55.7
	2) TWO	23	8.2	14	7.7
	3) THREE	0	0.0	0	0.0
	4) MORE THAN THREE	0	0.0	0	0.0
Q-17	When did you install your most recent fireplace or wood stove?				
	1) CAME WITH HOUSE Skip to Q-22	120	42.7	87	47.5
	2) 1 TO 5 YEARS AGO	124	44.1	75	41.0
	3) 6 TO 10 YEARS AGO	26	9.3	15	8.2
	4) MORE THAN 10 YEARS AGO	11	3.9	6	3.3
	9) DON'T KNOW/REFUSED	0	0.0	0	0.0

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-18	Was the wood stove or fireplace that you installed a replacement for an existing unit?				
	1) YES	32	19.9	18	18.8
	2) NO	129	80.1	78	81.3
Q-19	What was the approximate cost of purchasing and installing your wood stove or fireplace, including the pipe and chimney?				
	1) LESS THAN $500	49	30.4	26	27.1
	2) $500 TO $900	52	32.3	33	34.4
	3) $901 TO $1300	23	14.3	17	17.7
	4) MORE THAN $1300	16	9.9	10	10.4
	9) DON'T KNOW/REFUSED	21	13.0	10	10.4
Q-20	In your opinion, has or will your wood stove or fireplace pay for itself?				
	1) YES	142	88.2	83	86.5
	2) NO - Skip to Q-22	17	10.6	12	12.5
	9) DON'T KNOW/REFUSED	2	1.2	1	1.0
Q-21	Approximately how many years do you think it will take to pay for itself?				
	1) 1 TO 2 YEARS	69	48.6	36	43.4
	2) 3 TO 5 YEARS	45	31.7	29	34.9
	3) 6 TO 8 YEARS	9	6.3	4	4.8
	4) MORE THAN 8 YEARS	7	4.9	5	6.0
	9) DON'T KNOW/REFUSED	12	8.5	9	10.8

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-22	How many years have you burned wood?				
1)	1 YEAR - Only ask A in Q-23	41	14.6	27	14.8
2)	2 YEARS - Only ask A & B in Q-23	33	11.7	26	14.2
3)	3 YEARS TO 5 YEARS	76	27.0	40	21.9
4)	6 YEARS TO 10 YEARS	57	20.3	33	18.0
5)	MORE THAN 10 YEARS	61	21.7	44	24.0
9)	DON'T KNOW/REFUSED	13	4.6	13	7.1
Q-23	Approximately how many cords of wood did you burn:				
A.	THIS WINTER (1983-84)				
1)	LESS THAN 1 CORD	66	24.6	51	30.0
2)	1 TO 2 CORDS	63	23.5	42	24.7
3)	3 TO 4 CORDS	56	20.9	34	20.0
4)	5 TO 6 CORDS	32	11.9	18	10.6
5)	MORE THAN 6 CORDS	33	12.3	17	10.0
9)	DON'T KNOW/ REFUSED	18	6.7	8	4.7
B.	LAST WINTER (1982-83)				
1)	LESS THAN 1 CORD	48	21.1	40	28.0
2)	1 TO 2 CORDS	48	21.1	34	23.8
3)	3 TO 4 CORDS	41	18.1	23	16.1
4)	5 TO 6 CORDS	34	15.0	18	12.6
5)	MORE THAN 6 CORDS	33	14.5	17	11.9
9)	DON'T KNOW/ REFUSED	23	10.1	11	7.7

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-23 Cont'd					
C.	TWO WINTERS AGO (1981-82)				
1)	LESS THAN 1 CORD	40	20.6	32	27.4
2)	1 TO 2 CORDS	36	18.6	24	20.5
3)	3 TO 4 CORDS	38	19.6	23	19.7
4)	5 TO 6 CORDS	26	13.4	12	10.3
5)	MORE THAN 6 CORDS	34	17.5	17	14.5
9)	DON'T KNOW/ REFUSED	20	10.3	9	7.7
Q-24	Do you generally cut your own wood?				
1)	YES	193	68.7	110	60.1
2)	NO - Skip to Q-29	88	31.3	73	39.9
Q-25	How much less do you think it costs per cord to cut your own wood rather than to buy wood?				
1)	DON'T THINK IT COSTS LESS	22	11.4	18	16.4
2)	$10 LESS PER CORD	9	4.7	5	4.5
3)	$20 LESS	22	11.4	12	10.9
4)	$30 LESS	72	37.3	37	33.6
9)	DON'T KNOW/REFUSED	68	35.2	38	34.5

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-26	How far do you usually drive round trip to cut wood?				
1)	LESS THAN 20 MILES	56	29.0	23	20.9
2)	20 TO 60 MILES	77	39.9	48	43.6
3)	61 TO 100 MILES	24	12.4	18	16.4
4)	MORE THAN 100 MILES	27	14.0	14	12.7
9)	DON'T KNOW/REFUSED	9	4.7	7	6.4

Q-27 Why do you prefer to cut your own wood? (Only 2 answers)

	FIRST ANSWER				SECOND ANSWER			
	STATE		MPC		STATE		MPC	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) IT IS CHEAPER TO CUT THAN TO BUY	94	48.7	49	44.5	13	30.2	5	25.0
2) I CONSIDER IT A FORM OF RECREATION	81	42.0	55	50.0	18	41.9	9	45.0
3) I FEEL MORE SELF-SUFFICIENT	3	1.6	1	0.9	4	9.3	1	5.0
4) OTHER: SPECIFY	12	6.2	3	2.7	6	14.0	3	15.0
9) DON'T KNOW/REFUSED	3	1.6	2	1.8	2	4.7	2	10.0

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-28	Do you think firewood is more difficult to locate this year than last year?				
	1) YES	82	42.5	48	43.6
	2) NO	92	47.7	48	43.6
	9) DON'T KNOW/REFUSED	19	9.8	14	12.7
	Skip to Q-31				
Q-29	How much do you pay for a cord of wood?				
	1) LESS THAN $40	11	12.5	10	13.7
	2) $40 TO $50	24	27.3	19	26.0
	3) $51 TO $60	19	21.6	15	20.5
	4) $61 TO $75	14	15.9	9	12.3
	5) MORE THAN $75	2	2.3	2	2.7
	9) DON'T KNOW/REFUSED	18	20.5	18	24.7

Q-30 Why do you buy rather than cut your own wood? (Only 2 answers)

	FIRST ANSWER				SECOND ANSWER			
	STATE		MPC		STATE		MPC	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) TOO MUCH WORK	11	12.5	8	11.0	3	17.6	2	18.2
2) DON'T HAVE TRUCK OR SAW	17	19.3	14	19.2	6	35.3	3	27.3
3) TOO DANGEROUS	1	1.1	1	1.4	0	0.0	0	0.0
4) DON'T HAVE TIME	16	18.2	10	13.7	2	11.8	2	18.2
5) CHEAPER TO BUY	6	6.8	5	6.8	2	11.8	1	9.1
6) TOO DIFFICULT TO FIND FIREWOOD	2	2.3	2	2.7	1	5.9	0	0.0
7) OTHER: SPECIFY	20	22.7	18	24.7	3	17.6	3	27.3
9) DON'T KNOW/REFUSED	15	17.0	15	20.5	0	0.0	0	0.0

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-31	If the weather for the next five years is the same as this winter, do you think you will burn more, less, or about the same amount of wood than you burned this winter?				
1)	MORE	34	12.1	22	12.0
2)	LESS - Skip to Q-33	20	7.1	11	6.0
3)	ABOUT THE SAME Skip to Q-34	220	78.3	144	78.7
9)	DON'T KNOW/REFUSED	7	2.5	6	3.3

Q-32 Why do you think you will burn more wood? (Only 2 answers)

	FIRST ANSWER				SECOND ANSWER			
	STATE		MPC		STATE		MPC	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) UTILITY PRICES MAY GO UP	10	29.4	7	31.8	1	50.0	1	50.0
2) ANTICIPATE BUYING A MORE EFFICIENT STOVE	2	5.9	1	4.5	0	0.0	0	0.0
3) WOOD IS A CHEAPER WAY TO HEAT MY HOME	6	17.6	4	18.2	1	50.0	1	50.0
4) OTHER: SPECIFY	15	44.1	9	40.9	0	0.0	0	0.0
9) DON'T KNOW/REFUSED	1	2.9	1	4.5	0	0.0	0	0.0

Skip to Q-34

		STATE		MPC	
		NUMBER	PERCENT	NUMBER	PERCENT
Q-33	Why do you think you will burn less wood? (Only 2 answers)				
	1) CONCERNED ABOUT AIR POLLUTION	2	10.0	2	18.2
	2) ANTICIPATE CONSERVING MORE ENERGY	5	25.0	1	9.1
	3) FIREWOOD IS GETTING MORE DIFFICULT TO FIND	2	10.0	1	9.1
	4) OTHER: SPECIFY	11	55.0	7	63.6

Q-34 I am going to read a few newspaper statements that have been made about heating with wood, and I would like you to tell me whether you agree (1) or disagree (2) with these statements.

	STATE						MPC					
	Agree		Disagree		Don't Know/ Refused		Agree		Disagree		Don't Know/ Refused	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1) HEATING WITH WOOD IS INCONVENIENT	126	44.8	151	53.7	4	1.4	88	48.1	92	50.3	3	1.6
2) HEATING WITH WOOD IS CHEAPER THAN HEATING WITH GAS OR ELECTRICITY	216	76.9	46	16.4	19	6.8	134	73.2	35	19.1	14	7.7
3) HEATING WITH WOOD CAUSES EXTRA HOUSECLEANING CHORES	211	75.1	68	24.2	2	0.7	137	74.9	44	24.0	2	1.1
4) WOODBURNING IS A MAJOR SOURCE OF AIR POLLUTION	125	44.5	143	50.9	13	4.6	91	49.7	81	44.3	11	6.0

		STATE NUMBER	STATE PERCENT	MPC NUMBER	MPC PERCENT
Q-35	Approximately when was your home built?				
1)	BEFORE 1940	52	18.5	29	15.8
2)	1940 TO 1949	19	6.8	11	6.0
3)	1950 TO 1959	33	11.7	20	10.9
4)	1960 TO 1969	52	18.5	34	18.6
5)	1970 TO 1974	41	14.6	27	14.8
6)	1975 TO 1978	41	14.6	31	16.9
7)	1979 OR LATER	39	13.9	27	14.8
9)	DON'T KNOW/REFUSED	4	1.4	4	2.2

END SURVEY FOR WOODBURNERS. THANK YOU VERY MUCH FOR YOUR COOPERATION. GOOD-BYE.

SEX:

1)	Female	347	57.5	222	57.4
2)	Male	256	42.5	165	42.6

APPENDIX B

SAMPLING TECHNIQUE

APPENDIX B

SAMPLING TECHNIQUE

On the basis of current population estimates and specific MPC gas and electric service area boundaries supplied by the Montana Public Service Commission, ECO estimated that there are approximately 200,000 households which purchase electricity from MPC. The total number of Montana households was estimated to be slightly over 300,000.

Since the DNRC was primarily interested in estimating wood use for MPC electric customers, a sample was randomly drawn such that the MPC estimates would be "accurate" 95 percent of the time with a five percent error rate. The total sample size requirement was calculated to be 383.

On a statewide basis, 603 calls were completed of which 387 indicated that they were MPC electric customers, thus satisfying the stated precision and error rate objectives. At the state level, the error rate was somewhat lower because of the larger combined sample size (603 sample for both MPC customers and those who do not purchase electricity from MPC). The sampling frame, as developed and drawn by Dr. Kenneth Tiahrt (Chairman of the Montana State University Math Department), was as follows.

> The sampling frame utilized was based on random selection of phone numbers on a statewide basis. The 1970 census data for Montana cities was utilized to allow sample selection proportional to population. In general, every major phone prefix was selected, however, because a number of individual prefixes have very small populations it was necessary to pool these small phone exchanges and select one or two numbers to represent a combined group of the population.
>
> Following the completion of a preliminary analysis, fifty additional phone numbers were selected from the northwest area of the state to provide a more close distribution of respondents to 1980 county census data. This apparent discrepancy was due, at least in part, to allocation of sample size by city rather than by county and was relevant because the items of interest were regional in nature. It should be noted that even though the primary items of interest in this

survey were based on housing units the sample allocation was based on population. This was done because of a feeling that the population data was more reliable for sample selection and because no accurate data on numbers of residential phones is available. Clearly these are matters of judgement and could have been decided otherwise.

The actual random selection process was accomplished by a systematic draw of the determined count of phone numbers from each community. Each drawn phone number was then incremented by ten before a call was made. If such a phone number was a non-respondent for any reason (not in service, non-residential, refusal, etc.) the non-responding number was incremented by ten again and recalled. This process effectively provides that the predetermined number of calls to a given prefix will be completed. The randomness introduced by the ten incrementation also provides that newly connected and unlisted numbers will be contacted.

These sampling practices are in accord with the most recent techniques in telephone survey research as reported at meetings and in publications of the American Statistical Association and allied professional societies. Specific references include:

J. Waksberg, Sampling Methods for Random Digit Dialing, JASA 1978, V73, No361, p40-46

J. Fletcher & H. Thompson, Telephone Directory Samples and Random Telephone Number Generation, J of Broadcasting, 1974, V18.2, p187-191

S. Sudman, The Uses of Telephone Directories for Survey Sampling, J of Marketing Research, 1973, V10, p204-207

G. Glasser & G. Metzger, Random Digit Dialing as a Method of Telephone Sampling, 1972, J of Marketing Research, V9, p59-64

Comments on Telephone Sampling Procedure

A telephone survey rather than a mail survey was chosen for two reasons: 1) no mail list of MPC electric customers was available, and 2) the complexity of the questionnaire (i.e., requiring numerous question skips) which was of interest to the DNRC precluded mail survey techniques.

After the survey was administered, the sampling procedure was carefully examined and a potential systematic bias was discovered. Rural numbers may have been oversampled and urban numbers undersampled. Because

of the irregular nature of the MPC gas and electric service territory, certain variables such as electric saturation rates may have been overestimated. The overall effect on both the statewide survey or on the remainder of the MPC responses remain unclear.

This potential bias resulted from a uniform number of calls per three-digit telephone prefix by city. Although the number of calls per city directory was correct, the distribution of calls by prefix was skewed toward areas that appear to only have electrical service and not natural gas service. For example, in the Helena area, 20 completions out of a total of 29 were made from prefixes generally regarded as being within the city limits, hence having both gas and electrical service. If the number of calls for these specific prefixes had been weighted by the three-digit telephone prefix distribution, 26 calls would have been made for the "urban area" versus the actual 20 calls for this area. Since there is no possible way to fully determine if a three-digit prefix is either in or out of the city limits (frequently the extent of gas service), the potential bias could not have been completely eliminated through detailed three-digit prefix weighting in the sample. Nevertheless, had the sample been weighted by prefix, this distortion would have been less.

Although there is considerable speculation involved, the apparent sampling bias probably explains why the reported MPC electric saturation rate was 23 percent rather than a more likely figure of 15 percent at the current time. Comparisons for saturation rates are provided in Table B-1. With the exception of the variation between estimates by MPC and ECO for gas and electric saturation rates, the majority of the other estimates contained in Table B-1 appear to be similar.

TABLE B-1

SURVEY COMPARISONS OF SATURATION RATES

Type of Fuel	1980 Census[1] (State)	1979 Elrick/Lavidge[2] (State)	1984 ECO Survey[3] (State)
Gas	61%	60%	57%
Electricity	16%	14%	16%
Wood (Primary)	9%	8%	17%
Other	14%	18%	10%
TOTAL	100%	100%	100%

Type of Fuel	1982 MPC[4]	1984 ECO Survey for MPC Grid[5]
Gas	70%	58%
Electricity	12%	23%
Wood (Primary)	11%	13%
Other	7%	6%
TOTAL	100%	100%

Sources:

1 U.S. Department of Commerce, Bureau of the Census, "1980 Census, Detailed Housing Report," 1982.

2 Elrick & Lavidge, Inc., "The Pacific Northwest Residential Energy Survey," 1980, prepared for the Bonneville Power Administration and Pacific Northwest Utilities Conference Committee.

3 ECO Northwest, Helena, Montana, wood fuel use telephone survey, 1984, conducted for Montana Department of Natural Resources and Conservation, Energy Division.

4 Montana Power Company, Butte, Montana, "1982 Residential Survey, Executive Summary," 1982.

The sampling frame may also explain in part why the average age of houses was lower in the ECO survey than in previous surveys (see Table B-2). That is, if the areas just outside of city limits (or gas service area) were oversampled, the average home age would be lower than the actual home age. Much (approximately 60 percent) of the population growth in Montana seems to have occurred just outside of city boundaries. These newer homes tend to have a higher electric and saturation rate.

In addition to the aforementioned sample bias, it was also noted that individuals sometimes would claim that they purchased electricity from MPC when there was little, if any, chance that they actually could do so on the basis of telephone prefix location. In this case, consumer concern over the Colstrip rate case could have induced bias.

TABLE B-2

AVERAGE AGE OF HOUSE

State

Source	Age of House
Census 1980[1]	32.5 years
Elrick/Lavidge 1980[2]	30.0 years
ECO Northwest 1984[3]	28.1 years

MPC Electric Service Area

Source	Age of House
MPC 1982[4]	32.3 years
ECO Northwest 1984[3]	26.5 years

Estimates derived from:

1 U.S. Department of Commerce, Bureau of the Census, "1980 Census, Detailed Housing Report," 1982.

2 Elrick & Lavidge, Inc., "The Pacific Northwest Residential Energy Survey," 1980, prepared for the Bonneville Power Administration and Pacific Northwest Utilities Conference Committee.

3 ECO Northwest, Helena, Montana, wood fuel use telephone survey, 1984, conducted for Montana Department of Natural Resources and Conservation, Energy Division.

4 Montana Power Company, Butte, Montana, "1982 Residential Survey, Executive Summary," 1982.

APPENDIX C

BASIC PROGRAM SOURCE CODE
WEST MODEL

```
10 REM ================================================================
20 REM ======= PROGRAM: WOODSTOV                                  ======
30 REM ======= AUTHOR : RICHARD DODGE                            ======
40 REM ======= DATE   : 04/15/84                                 ======
50 REM ======= DESC   : PROGRAM WOODSTOV ROUTINES:               ======
60 REM =======          : 1000 - SET SYSTEM PARAMETERS           ======
70 REM =======          : 2000 - SET SEMI-PERM INPUT DATA        ======
80 REM =======          : 3000 - INPUT DYNAMIC DATA FROM SCREEN  ======
90 REM =======          : 4000 - CRUNCH DATA ROUTINES            ======
100 REM ======          : 5000 - OUTPUT PARAMETERS & DATA        ======
110 REM ======          : 6000 - MORE WOODSTOV?                  ======
120 REM ================================================================
130 REM
140 REM
500 GOSUB 1000          REM SET SYSTEM PARAMETERS
510 GOSUB 2000          REM READ DATA STATEMENTS
520 GOSUB 3000          REM INPUT SCREEN DATA
530 GOSUB 4000          REM CRUNCH DATA
535 GOSUB 4900          REM TOTAL QT
540 GOSUB 5000          REM PRINT OUTPUT
550 GOTO  520           MORE WOODSTOV PRINT
1000 REM ROUTINE TO SET SYSTEM PARAMETERS
1005     KEY OFF : CLS          : REM THIS STATEMENT IS FOR IBM PC ONLY
1006     PO$ = CHR$(12)         : REM PRINTER CONTROL FOR NEW PAGE
1010     N=13                   : REM TERM
1020     DIM PE(N),HS(N),PW(N),TG(N),TT(N),APC(N),TC(N),CT(N),QT(N)
1030     DIM COT(N),AFCS(N),STRW(N),HW(N),Q(N,N),TWV(N),THL(N),TED(N),WV(N)
1500     REM DEFINE FUNCTIONS IN HERE
1510         DEF FNA(V1,V2,V3)=V1*(1+V2)^(V3-1)       : REM POWER FUNCTION N-1
1520     QT(1) = QINP
1999     RETURN
2000 REM ROUTINE TO SET DATA
2005     BASE = 1984            : REM BASE YEAR
2010     HMT = 200000!          : REM HOUSEHOLDS IN MONTANA BASE YEAR
2020     HG = .023              : REM HOUSEHOLD GROWTH IN MONTANA (ANNUAL)
2030     BR = 62!               : REM BTU REQUIREMENT IN E06
2040     BG = -.025             : REM BTU REQUIREMENT GROWTH (ANNUAL)
2050     WE = .4                : REM WOOD EFFICIENCY
2060     WG = .01               : REM WOOD EFFICIENCY GROWTH (ANNUAL)
2070     BPC = 19               : REM BTUs PER CORD IN E06
2080     WP = 35                : REM PRICE OF WOOD PER CORD IN 1984 $
2090     GW = 0                 : REM PRICE OF WOOD GROWTH (REAL ANNUAL)
2100     GE = .6                : REM GAS EFFICIENCY
2110     GG = .01               : REM GAS EFFICIENCY GROWTH (ANNUAL)
2120     GP = 5.2               : REM PRICE GAS PER E06 BTUs IN 1984 $
2130     PG = .027              : REM PRICE OF GAS GROWTH (REAL ANNUAL)
2140     PE(1) = 12.33          : REM PRICE ELECTRICITY PER E06 BTU IN 1984 $
2150     PE(2) = 17.64          : REM PRICE OF ELEC 1985
2160     PE(3) = 19.66          : REM PRICE OF ELEC 1986
2161     PE(4) = 18.37 : PE(5) = 17.99 : PE(6) = 17.36 : PE(7) = 17.37
2162     PE(8) = 16.84 : PE(9) = 16.35 : PE(10)= 18.12
2163     PE(11)= 16.76 : PE(12)= 16.35
2180     QINP = 2.6             : REM CORDS WOOD PER HOUSEHOLD BASE YEAR
2190     EW = -.5               : REM ELASTICITY OF WOOD
2200     EF = .5                : REM ELASTICITY OF OTHER FUELS
2210     GAMMA = .25            : REM GAMMA ADJUSTMENT (0-2)
2230     CI = -.5               : REM COST OF INCONVENIENCE (SUBJECTIVE 0-1)
2240     PI = -.5               : REM POLLUTION IMPACT (SUBJECTIVE 0-1)
2250     WBE = 1!               : REM WOOD BURNING ETHIC (SUBJECTIVE 0-1)
2260     SG = .66               : REM SATURATION OF GAS IN PERCENT
2270     SE = .15               : REM SATURATION OF ELECTRICITY IN PERCENT
2280     SW = .5                : REM SATURATION OF WOOD IN PERCENT
2290     AG = 8.999999E-03      : REM SG GROWTH RATE (ANNUAL)
2300     AE = .014              : REM SE GROWTH RATE (ANNUAL)
2310     WSC = 1000             : REM COST OF A WOODSTOVE IN $
2320     ESC = 750!             : REM COST OF ELECTRICAL HEAT IN $
2330     GSC = 2500             : REM COST OF GAS HEAT (FURNACE) IN $
2340     DR = .06               : REM DISCOUNT RATE REAL
2350     NW = 10                : REM TERM OF WOODSTOVE IN YEARS
2360     NO = 20                : REM TERM OF OTHER IN YEARS
2370     OMRW = .48             : REM OPERATION, MAINT, REPAIR OF WOOD STOVE
2380     OORM = .2              : REM OPERATION, MAINT, REPAIR OF OTHER FURNACE
2390     DW = 1                 : REM DEPRECIATION OF WOODSTOVE (0-1)
2400     DO = 1                 : REM DEPRECATION OF OTHER (0-1)
2410     WMAX = 30              : REM BTU OUTPUT PER STOVE (MAXIMUM)
2420     C = .0002              : REM SATURATION CONVERSTION RATE
2430     DUM = 0                : REM DUMMY $ PER CORD
2440     NPW=WP + DUM
```

```
2450     CW = (WSC*(DR/(1-(1+DR)^-NW)))*(1+OMRW)*DW   : REM CAP COSTS WOOD
2460     CE = (ESC*(DR/(1-(1+DR)^-NO)))*(1+OORM)*DO   : REM CAP COSTS ELEC
2470     CG = (GSC*(DR/(1-(1+DR)^-NO)))*(1+OORM)*DO   : REM CAP COSTS GAS
2999     RETURN
3000 REM ROUTINE TO INPUT DATA ON SCREEN
3010 CLS
3020 PRINT STRING$(28," ");"Woodstove Program"
3030 PRINT
3040 PRINT "Edit a Variable:"
3050 PRINT "A: Base Year (BASE) =";BASE;TAB(40);"I: Gas Saturation (SG) =";SG
3060 PRINT "B: Households in Base (HMT) =";HMT;TAB(40);"J: Elec. Saturation (SE)
 =";SE
3070 PRINT "C: Household Growth (HG) =";HG;TAB(40);"K: Wood Saturation (SW) =";S
W
3080 PRINT "D: Price of Wood/Cord (WP) =";WP;TAB(40);"L: Woodstove Cost (WSC) ="
;WSC
3090 PRINT "E: Price of Wood Growth (GW) =";GW;TAB(40);"M: Elec. Furnace Cost (E
SC) =";ESC
3100 PRINT "F: Price of Gas/E06 BTUs (GP) =";GP;TAB(40);"N: Gas Furnace Cost (GS
C) =";GSC
3110 PRINT "G: Price of Gas Growth (PG) =";PG;TAB(40);"O: Saturation Conv. Rate
(C) =";C
3120 PRINT "H: Cords of Wood (QINP) =";QINP;TAB(40);"P: Price of Electricity (PE
)"
3125 PRINT
3130 PRINT
3140 PRINT
3150 PRINT
3160 PRINT
3170 PRINT
3180 PRINT "Z: Run Woodstove"
3190 PRINT
3200 PRINT "Choice:"
3220 GOSUB 7000   REM GET COMMAND INPUT FROM USER
3230 IF Q$="Z" THEN RETURN   : REM RUN WOODSTOVE
3240 PRINT
3250 ON ASC(Q$)-64 GOSUB 3300,3320,3340,3360,3380,3400,3420,3440,3460,3480,3500,
3520,3540,3560,3580,3600
3260 GOTO 3000
3300 GOSUB 7500    : REM CLEAR LINE AND POSITION CURSOR
3305 INPUT "Base Year (BASE)";BASE
3310 IF BASE<1980 THEN GOTO 3300
3315 RETURN
3320 GOSUB 7500
3325 INPUT "Households in Base (HMT)";HMT
3330 IF HMT<100000! THEN 3320
3335 RETURN
3340 GOSUB 7500
3345 INPUT "Household Growth (HG)";HG
3350 IF HG<0 THEN 3340
3355 RETURN
3360 GOSUB 7500
3365 INPUT "Price of Wood/Cord (WP)";WP
3370 IF WP<0 THEN 3360
3375 RETURN
3380 GOSUB 7500
3385 INPUT "Price of Wood Growth (GW)";GW
3390 IF GW<0 THEN 3380
3395 RETURN
3400 GOSUB 7500
3405 INPUT "Price of Gas/E06 BTUs (GP)";GP
3410 IF GP<0 THEN 3400
3415 RETURN
3420 GOSUB 7500
3425 INPUT "Price of Gas Growth (PG)";PG
3430 IF PG<0 THEN 3420
3435 RETURN
3440 GOSUB 7500
3445 INPUT "Cords of Wood (QINP)";QINP
3450 IF QINP<0 THEN 3440
3455 RETURN
3460 GOSUB 7500
3465 INPUT "Gas Saturation (SG)";SG
```

```
3470 IF SG<0 THEN 3460
3475 RETURN
3480 GOSUB 7500
3485 INPUT "Elec. Saturation (SE)";SE
3490 IF SE<0 THEN 3480
3495 RETURN
3500 GOSUB 7500
3505 INPUT "Wood Saturation (SW)";SW
3510 IF SW<0 THEN 3500
3515 RETURN
3520 GOSUB 7500
3525 INPUT "Woodstove Cost (WSC)";WSC
3530 IF WSC<0 THEN 3520
3535 RETURN
3540 GOSUB 7500
3545 INPUT "Elec. Furnace Cost (ESC)";ESC
3550 IF ESC<0 THEN 3540
3555 RETURN
3560 GOSUB 7500
3565 INPUT "Gas Furnace Cost (GSC)";GSC
3570 IF GSC<0 THEN 3560
3575 RETURN
3580 GOSUB 7500
3585 INPUT "Saturation Conv. Rate (C)";C
3590 IF C<0 THEN 3580
3595 RETURN
3600 REM PRICE OF ELECTRICITY EDIT
3610 CLS
3620 PRINT "Price of Electricity"
3630 PRINT
3640 I=BASE
3650 FOR J=1 TO N-1
3660     PRINT "  ";CHR$(J+64);":";I;"=";PE(J)
3670     I=I+1
3680 NEXT J
3690 PRINT
3695 PRINT
3700 PRINT
3710 PRINT "Z: End Price of Electricity Editing"
3720 PRINT
3730 PRINT "Choice:"
3740 GOSUB 7000    : REM GET USER INPUT
3750 J=ASC(Q$)-64
3760 IF J>0 AND J<=N-1 THEN GOSUB 3800
3770 IF Q$="Z" THEN RETURN
3780 GOTO 3600
3800 PRINT
3810 PRINT "Price of Electricity in";BASE+J-1;
3820 INPUT PE(J)
3830 IF PE(J)<0 THEN 3800
3340 RETURN
3999     RETURN
4000 REM ROUTINE TO CRUNCH DATA
4005     CLS
4007     PRINT "                                Please stand by ..."
4010     FOR IC = 1 TO N-1
4020         GOSUB 4200  :  REM GET HS(IC), PW(IC), TG(IC), TT(IC), APC(IC)
4040         GOSUB 4500  :  REM TC(IC), CT(IC), COT(IC)
4060         GOSUB 4700  :  REM GET Q(IC,IC) THE ADD ON TO QINP
4080     NEXT IC
4083         GOSUB 4900  :  REM GET GT(IC)
4084         GOSUB 4800  :  REM GET TWV(IC),THL(IC),TED(IC),WV(IC)
4099     RETURN
4200     REM ROUTINE TO COMPUTE HS(IC), PW(IC), TG(IC), TT(IC)
4210         HS(IC)=FNA(HMT,HG,IC)
4220         PW(IC)=((NPW/FNA(WE,WG,IC))/BPC)*FNA(1,GW,IC)
4230         TG(IC)=(GP/FNA(GE,GG,IC))*FNA(1,PG,IC)
4240         V1=FNA(SG,AG,IC) : V2=FNA(SE,AE,IC)
4250         TT(IC)=(V1*TG(IC)+V2*PE(IC))/(V1+V2)
4260         APC(IC)=(V1*CG+V2*CE)/(V1+V2)
4299     RETURN
4500     REM ROUTINE TO COMPUTE TC(IC), CT(IC), COT(IC)
```

```
4510          V1=FNA(BR,BG,IC) : TC(IC)=CW*V1/WMAX
4520          CT(IC)=TC(IC)+PW(IC)*V1
4530          COT(IC)=APC(IC)+TT(IC)*V1
4540          AFCS(IC)=COT(IC)-CT(IC)
4550          STRW(IC)=SW+C*AFCS(IC)*(1-(1-GAMMA)^(IC-1))
4560          HW(IC)=STRW(IC)*HS(IC)*(1+CI+PI+WBE)
4599      RETURN
4700      REM ROUTINE TO CALCULATE Q(IC,IC)
4705      IF IC = 1 THEN 4799    : REM DO NOT CALCULATE FOR YEAR 1
4710      V1=(PW(IC)/PW(IC-1)-1) : V2=(TT(IC)/TT(IC-1)-1)
4720      FOR ID = IC TO N-1
4730          V3=EW*(1-(1-GAMMA)^(ID-(IC-1))) : V4=EF*(1-(1-GAMMA)^(ID-(IC-1)))
4740          Q(ID,IC-1)=QINP*(V1*V3+V2*V4)
4750      NEXT ID
4799      RETURN
4800 REM ROUTINE TO CALCULATE TWV(IC),THL(IC),TED(IC), & WV(T)
4805      FOR IC = 1 TO N-1
4810      TWV(IC)=(HW(IC)*QT(IC))
4820      THL(IC)=HS(IC)*FNA(BR,BG,IC)
4830      TED(IC)=TWV(IC)*BPC*FNA(WE,WG,IC)
4840      WV(IC)=TED(IC)/THL(IC)
4845      NEXT IC
4899      RETURN
4900 REM ROUTINE TO CALCULATE QT TOTALS
4910      FOR IC = 1 TO N-1
4915      QT(IC) = QINP
4920        FOR ID=1 TO IC
4930          QT(IC)=QT(IC)+Q(IC,ID)
4940        NEXT ID
4950      NEXT IC
4999      RETURN
5000 REM ROUTINE TO PRINT OUTPUT
5010      LPRINT "1.  Woodstove Base Data"
5015      LPRINT
5020      LPRINT "Base Year (BASE) = ";BASE
5030      LPRINT "Projection Term (N) = ";N
5040      LPRINT "Households in Base Year (HMT) = ";HMT
5050      LPRINT "Household Growth (HG) = ";HG
5060      LPRINT "BTU Requirement (BR) in E06 = ";BR
5065      LPRINT "BTU Requirement Growth Rate (BG) = ";BG
5070      LPRINT "Wood Efficiency (WE) = ";WE
5080      LPRINT "Wood Efficiency Growth (WG) = ";WG
5090      LPRINT "BTUs Per Cord of Wood (BPC) in E06 = ";BPC
5100      LPRINT "Price of Wood Per Cord (WP) = ";WP
5110      LPRINT "Price of Wood Growth (GW) = ";GW
5120      LPRINT "Gas Efficiency (GE) = ";GE
5130      LPRINT "Gas Efficiency Growth (GG) = ";GG
5140      LPRINT "Price Gas in Base Year (GP) Per E06 BTUs = ";GP
5150      LPRINT "Price of Gas Growth (PG) = ";PG
5160      LPRINT "Quantity of Wood Base Year in Cords (QINP) = ";QINP
5170      LPRINT "Elasticity of Wood (EW) = ";EW
5180      LPRINT "Elasticity of Other Fuels (EF) = ";EF
5190      LPRINT "Gamma Adjustment (GAMMA) = ";GAMMA
5200      LPRINT "Cost of Inconvenience (CI) = ";CI
5210      LPRINT "Pollution Impact (PI) = ";PI
5220      LPRINT "Woodburning Ethic (WBE) = ";WBE
5230      LPRINT "Saturation of Gas (SG) = ";SG
5240      LPRINT "Saturation of Electricity (SE) = ";SE
5250      LPRINT "Saturation of Wood (SW) = ";SW
5260      LPRINT "Saturation of Gas Growth Rate (AG) = ";AG
5270      LPRINT "Saturation of Electricity Growth Rate (AE) = ";AE
5280      LPRINT "Cost of a Woodstove (WSC) = ";WSC
5290      LPRINT "Cost of an Electrical Furnace (ESC) = ";ESC
5300      LPRINT "Cost of a Gas Furnace (GSC) = ";GSC
5310      LPRINT "Discount Rate in Real Terms (DR) = ";DR
5320      LPRINT "Woodstove Projected Life (NW) = ";NW
5330      LPRINT "Projected Life of Other Furnaces (NO) = ";NO
5340      LPRINT "Operation, Maintenance, Repair Costs of Woodstove (OMRW) = ";OM
RW
5350      LPRINT "Operation, Maintenance, Repair Costs of Other Furnaces (OORM) =
 ";OORM
5360      LPRINT "Depreciation of Woodstove (DW) = ";DW
5370      LPRINT "Depreciation of Other Furnaces (DO) = ";DO
```

```
5380     LPRINT "BTU Output Per Stove (WMAX) = ";WMAX
5390     LPRINT "Saturation Conversion Rate (C) = ";C
5400     LPRINT "Dummy Add On $ Per Cord (DUM) = ";DUM
5405     LPRINT "New Price of Wood (NPW) = ";NPW
5410     LPRINT "Capacity Costs of Wood (CW) = ";CW
5420     LPRINT "Capcity Costs of Elec (CE) = ";CE
5430     LPRINT "Capacity Costs of  Gas (CG) = ";CG
5440     LPRINT : LPRINT
5450     LPRINT "2.  Woodstove Intermediate Output"
5460     LPRINT
5470     LPRINT "                  Price     Price     Price     Price";
5480     LPRINT "       House      Wood/      Gas/     Elec/    Other/";
5490     LPRINT "Year   Holds     E06BTU    E06BTU    E06BTU    E06BTU";
5500     LPRINT "====   =====     ======    ======    ======    ======"
5510     FOR IC = 1 TO N-1
5520     LPRINT USING "####";IC+BASE-1;
5530     LPRINT USING "########";HS(IC);
5540     LPRINT USING "#######.##";PW(IC);TG(IC);PE(IC);TT(IC)
5550     NEXT IC
5560     LPRINT : LPRINT : LPRINT
5570     LPRINT "Year       APC        TC        CT       COT      AFCS      STR
W        HW";
5580     LPRINT "====     ======    ======    ======    ======    ======    ====
=    ======"
5590     FOR IC = 1 TO N-1
5600     LPRINT USING "####";IC+BASE-1;
5610     LPRINT USING "#######.##";APC(IC);TC(IC);CT(IC);COT(IC);AFCS(IC);STRW(I
C);HW(IC)
5620     NEXT IC
5630     LPRINT : LPRINT : LPRINT
5640     LPRINT "3.  Woodstove Add On Matrix Output"
5645     LPRINT
5650     FOR IC = 1 TO N-1
5680         LPRINT USING "######";IC;
5690     NEXT IC
5695     LPRINT
5700     FOR IC = 1 TO N-1
5710         LPRINT USING "##";IC;
5720         FOR ID = 1 TO IC
5730             LPRINT USING "##.###";Q(IC,ID);
5740         NEXT ID
5745         LPRINT
5750     NEXT IC
5760     LPRINT : LPRINT : LPRINT
5770     LPRINT "4.  Woodstove Projected Output"
5775     LPRINT
5780     LPRINT "Year         Q       TWV       THL       TED        WV";
5790     LPRINT "====     ======    ======    ======    ======    ======"
5800     FOR IC = 1 TO N-1
5810     LPRINT USING "####";IC+BASE-1;
5820     LPRINT USING "#######.##";QT(IC);
5822     LPRINT USING "##########";TWV(IC);THL(IC);TED(IC);
5824     LPRINT USING "#######.##";WV(IC)
5830     NEXT IC
5999     RETURN
6000 REM ROUTINE TO REQUEST MORE WOODSTOV
6999 RETURN
7000 REM GET INPUT FROM USER
7010 LOCATE 20,9,0 : PRINT "  " : LOCATE 20,9,1
7020 Q$=INKEY$ : IF Q$="" THEN 7020
7030 IF Q$>="a" AND Q$<="z" THEN Q$=CHR$(ASC(Q$)-32)
7040 PRINT Q$
7050 IF Q$<"A" OR Q$>"Z" THEN 7000
7060 RETURN
7500 LOCATE 22,1,0
7510 PRINT STRING$(70," ")
7520 PRINT STRING$(70," ")
7530 LOCATE 22,1,1
7540 RETURN
```

APPENDIX D

WOODSTOV/2

APPENDIX D

WOODSTOV/2

One of the contractual work tasks involved a review of the WOODSTOV/2 simulation model by Norman L. Marshall. This system had been used in both New England and Portland to estimate and project wood consumption patterns. To become acquainted with the model, the entirety of Marshall's first and later simulation variations should be reviewed. The original work, entitled "The Dynamics of Residential Wood-Energy Use in New England 1970-2000" (Resource Policy Center, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire) should be reviewed before other versions. Appendix I (pages 119-182) of WOODSTOV/2 documentation is particularly important because these pages provide both the equation structure and a narrative describing why a particular specification was chosen.

Most analysts are generally aware of the specifics of either end use or econometric models since such techniques are common practice among forecasters. Most analysts, however, are not as familiar with the systems simulation approach as are engineers. Although the WEST system is also developed along the lines of a "systems" model, the procedure is far less complex and more variables are directly measurable.

The complexity of the WOODSTOV/2 system and lack of data were the primary reasons for developing a new technique, presumably better suited to Montana and the Northwest. Model complexity should not be equated with sophistication. One of the essential rules in model development (Occam's Razor) state that:

> Entities should not be increased in number beyond what is necessary. That is to say, of two explanations, both of which account for the known facts, choose the one that requires the fewest additional assumptions.

Following are examples of several examples of the parameter selection that detract from the usefulness of WOODSTOV/2 as a forecasting method.

1) Pages 123-24. Marshall assumes that penetration will be 20 percent when average wood fuel cost savings are $200, and 50 percent when savings are $1,000 per year. No explanation is provided.

2) Various Pages. Marshall assumes that pollution and the wood-burning ethic are influential factors on wood use. He then sets these parameters to zero influence, presumably because they cannot be measured.

3) Page 126. Marshall assumes that penetration on existing homes will be zero when perceived payback period is 10 years and 20 percent when the payback is less than five years. Again, there is no empirical basis for such judgments.

4) Page 129. The effect of penetration on capacity costs is assumed to be zero when penetration is zero, and five-fold the benchmark cost when penetration reaches 60 percent.

5) Page 131. When perceived payback is negative, Marshall resets the value to a very large, positive number.

6) Page 132. When the average savings is $200 per year, Marshall assumes that 20 percent of the home heating needs are served by wood. When the savings is $1,000, that fraction rises to 95 percent.

7) Page 144. Inconvenience costs range from $200 per year when average capacity installed is zero to $1,000 and when 80 percent or more of the heating needs are met by wood.

8) Page 163. The effect of self-cut wood on price is assumed to rise 100 percent as the adoption rate climbs to 40 percent.

These assumptions are examples only. One will no doubt find several such "judgments" per algorithm, not unlike the WEST system.

Both the systems (WEST model and WOODSTOV/2) produce nearly the same results, probably by chance alone. ECO's choice was to develop a system involving fewer assumptions, fewer variables, and far fewer intervariable linkages as well as some degree of validation. After review of the original WOODSTOV/2 system, the DNRC concurred that WOODSTOV/2 was not appropriate for use.

APPENDIX E

SAMPLE SIMULATION RUNS

1. Woodstove Base Data

LOW SCENARIO

Base Year (BASE) = 1984
Projection Term (N) = 13
Households in Base Year (HSINP) = 200000
Household Growth (HSG) = .02
BTU Requirement (BTUR) in E06 = 62
BTU Requirement Growth Rate (BTURG) = -.025
Wood Efficiency (EW) = .4
Wood Efficiency Growth (EWG) = .01
BTUs Per Cord of Wood (BTUW) in E06 = 19
Price of Wood Per Cord in 1984 (PWINP) = 40
Price of Wood Growth (PWG) = .03
Gas Efficiency (EG) = .6
Gas Efficiency Growth (EGG) = .01
Price Gas in Base Year (PGINP) Per E06 BTUs = 4.35
Price of Gas Growth (PGG) = .022
Quantity of Wood Base Year in Cords (QINP) = 2.6
Elasticity of Wood (ELW) = -.75
Elasticity of Other Fuels (ELO) = .25
Gamma Adjustment (GAMMA) = .1
Cost of Inconvenience (CI) = -.5
Pollution Impact (PI) = -.5
Woodburning Ethic (WBE) = 1
Saturation of Gas (SATG) = .66
Saturation of Electricity (SATE) = .15
Saturation of Wood (SATW) = .5
Saturation of Gas Growth Rate (SATGG) = .014
Saturation of Electricity Growth Rate (SATEG) = 8.999999E-03
Cost of a Woodstove (WSC) = 1000
Cost of an Electrical Furnace (ESC) = 750
Cost of a Gas Furnace (GSC) = 2500
Discount Rate in Real Terms (DR) = .06
Woodstove Projected Life (NW) = 10
Projected Life of Other Furnaces (NO) = 20
Operation, Maintenance, Repair Costs of Woodstove (OMRW) = .6
Operation, Maintenance, Repair Costs of Other Furnaces (OMRO) = .1
Depreciation of Woodstove (DW) = 1
Depreciation of Other Furnaces (DO) = 1
BTU Output Per Stove (WMAX) = 20
Saturation Conversion Rate (C) = .0001
Dummy Add On $ Per Cord (DUM) = 0
New Price of Wood (NPW) = 40
Capacity Costs of Wood (PWC) = 217.3889
Capcity Costs of Elec (PEC) = 71.9273
Capacity Costs of Gas (PGC) = 239.7577

2. Woodstove Intermediate Output

Year	House Holds	Price Wood/ E06BTU	Price Gas/ E06BTU	Price Elec/ E06BTU	Price Other/ E06BTU
1984	200000	5.26	7.25	12.33	8.19
1985	204000	5.37	7.34	13.55	8.48
1986	208080	5.47	7.42	14.77	8.77
1987	212242	5.58	7.51	16.00	9.06
1988	216486	5.69	7.60	17.22	9.35
1989	220816	5.81	7.69	18.44	9.64
1990	225232	5.92	7.78	19.66	9.93
1991	229737	6.04	7.87	19.66	10.00
1992	234332	6.16	7.97	19.66	10.06
1993	239018	6.28	8.06	19.66	10.13
1994	243799	6.40	8.16	19.66	10.20
1995	248675	6.53	8.26	19.66	10.28

Year	APC	PWCA	TCW	TCO	AFCS	STRW	HSW
1984	208.68	673.91	1000.22	716.50	-283.72	0.50	100000.00
1985	208.80	657.06	981.52	721.55	-259.96	0.50	101469.70
1986	208.93	640.63	963.24	725.99	-237.25	0.50	103102.00
1987	209.05	624.62	945.39	729.95	-215.44	0.49	104881.60
1988	209.18	609.00	927.95	733.24	-194.71	0.49	106793.60
1989	209.30	593.78	910.91	736.01	-174.90	0.49	108826.50
1990	209.42	578.93	894.26	738.28	-155.98	0.49	110970.10
1991	209.54	564.46	877.99	728.67	-149.32	0.49	113078.80
1992	209.67	550.35	862.09	719.26	-142.83	0.49	115259.70
1993	209.79	536.59	846.56	710.07	-136.49	0.49	117510.70
1994	209.91	523.17	831.38	701.07	-130.31	0.49	119830.10
1995	210.03	510.09	816.55	692.26	-124.28	0.49	122216.60

3. Woodstove Add On Matrix Output.

```
     1     2     3     4     5     6     7     8     9    10    11    12
 1 0.000
 2-0.002 0.000
 3-0.003-0.002 0.000
 4-0.004-0.003-0.002 0.000
 5-0.005-0.004-0.003-0.002 0.000
 6-0.006-0.006-0.005-0.003-0.002 0.000
 7-0.007-0.007-0.006-0.005-0.004-0.002 0.000
 8-0.008-0.008-0.007-0.006-0.005-0.004-0.003 0.000
 9-0.009-0.009-0.008-0.007-0.006-0.005-0.007-0.003 0.000
10-0.009-0.009-0.009-0.008-0.008-0.007-0.009-0.006-0.003 0.000
11-0.010-0.010-0.010-0.009-0.009-0.008-0.012-0.009-0.006-0.003 0.000
12-0.011-0.011-0.010-0.010-0.010-0.009-0.014-0.012-0.009-0.006-0.003 0.000
```

4. Woodstove Projected Output

Year	Q	TWV	THL	TED	WEV
1984	2.60	260000	12400000	1976000	0.16
1985	2.60	263664	12331800	2023385	0.16
1986	2.60	267593	12263980	2074588	0.17
1987	2.59	271748	12196520	2127866	0.17
1988	2.59	276086	12129440	2183449	0.18
1989	2.58	280574	12062730	2241133	0.19
1990	2.57	285183	11996380	2300725	0.19
1991	2.56	289373	11930400	2357878	0.20
1992	2.55	293433	11864790	2414869	0.20
1993	2.53	297367	11799530	2471715	0.21
1994	2.51	301178	11734630	2528432	0.22
1995	2.49	304872	11670090	2585030	0.22

MEDIUM SCENARIO

1. Woodstove Base Data

Base year (BASE) = 1984
Projection Term (N) = 13
Households in Base Year (HMT) = 200000
Household Growth (HG) = .023
BTU Requirement (BR) in E06 = 62
BTU Requirement Growth Rate (BG) = -.025
Wood Efficiency (WE) = .4
Wood Efficiency Growth (WG) = .01
BTUs Per Cord of Wood (BPC) in E06 = 19
Price of Wood Per Cord (WP) = 35
Price of Wood Growth (GW) = 0
Gas Efficiency (GE) = .6
Gas Efficiency Growth (GG) = .01
Price Gas in Base Year (GP) Per E06 BTUs = 4.35
Price of Gas Growth (PG) = .027
Quantity of Wood Base Year in Cords (QINP) = 2.6
Elasticity of Wood (EW) = -.5
Elasticity of Other Fuels (EF) = .5
Gamma Adjustment (GAMMA) = .25
Cost of Inconvenience (CI) = -.5
Pollution Impact (PI) = -.5
Woodburning Ethic (WBE) = 1
Saturation of Gas (SG) = .66
Saturation of Electricity (SE) = .15
Saturation of Wood (SW) = .5
Saturation of Gas Growth Rate (AG) = 8.999999E-03
Saturation of Electricity Growth Rate (AE) = .014
Cost of a Woodstove (WSC) = 1000
Cost of an Electrical Furnace (ESC) = 750
Cost of a Gas Furnace (GSC) = 2500
Discount Rate in Real Terms (DR) = .06
Woodstove Projected Life (NW) = 10
Projected Life of Other Furnaces (NO) = 20
Operation, Maintenance, Repair Costs of Woodstove (OMRW) = .48
Operation, Maintenance, Repair Costs of Other Furnaces (OORM) = .2
Depreciation of Woodstove (DW) = 1
Depreciation of Other Furnaces (DO) = 1
BTU Output Per Stove (WMAX) = 30
Saturation Conversion Rate (C) = .0002
Dummy Add On $ Per Cord (DUM) = 0
New Price of Wood (NPW) = 35
Capacity Costs of Wood (CW) = 201.0847
Capcity Costs of Elec (CE) = 78.46615
Capacity Costs of Gas (CG) = 261.5538

2. Woodstove Intermediate Output

Year	House Holds	Price Wood/ E06BTU	Price Gas/ E06BTU	Price Elec/ E06BTU	Price Other/ E06BTU
1984	200000	4.61	7.25	12.33	8.19
1985	204600	4.56	7.37	17.64	9.28
1986	209306	4.51	7.50	19.66	9.77
1987	214120	4.47	7.62	18.87	9.73
1988	219045	4.43	7.75	17.99	9.68
1989	224083	4.38	7.88	17.36	9.67
1990	229237	4.34	8.01	17.37	9.79
1991	234509	4.30	8.15	16.84	9.80
1992	239903	4.25	8.29	16.35	9.83
1993	245420	4.21	8.43	18.12	10.29
1994	251065	4.17	8.57	16.76	10.15
1995	256840	4.13	8.71	16.35	10.19

Year	APC	TC	CT	COT	AFCS	STRW	HW
1984	227.65	415.58	701.10	735.47	34.37	0.50	100000.00
1985	227.51	405.19	680.82	788.56	107.74	0.51	103402.20
1986	227.37	395.06	661.14	803.02	141.89	0.51	107251.50
1987	227.24	385.18	642.04	786.40	144.36	0.52	110634.00
1988	227.10	375.55	623.51	769.32	145.81	0.52	113888.90
1989	226.96	366.16	605.53	755.32	149.80	0.52	117161.60
1990	226.82	357.01	588.08	748.18	160.11	0.53	120652.30
1991	226.68	348.08	571.15	735.81	164.66	0.53	123946.60
1992	226.54	339.38	554.71	724.15	169.44	0.53	127267.10
1993	226.40	330.90	538.77	734.21	195.45	0.54	131583.20
1994	226.26	322.62	523.29	714.63	191.34	0.54	134599.10
1995	226.12	314.56	508.27	704.31	196.03	0.54	138064.40

3. Woodstove Add On Matrix Output

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.000											
2	0.046	0.000										
3	0.081	0.020	0.000									
4	0.107	0.035	0.002	0.000								
5	0.127	0.047	0.004	0.001	0.000							
6	0.142	0.055	0.005	0.003	0.003	0.000						
7	0.153	0.062	0.005	0.003	0.005	0.007	0.000					
8	0.161	0.067	0.006	0.004	0.007	0.012	0.004	0.000				
9	0.167	0.070	0.007	0.004	0.008	0.016	0.007	0.004	0.000			
10	0.172	0.073	0.007	0.005	0.009	0.020	0.009	0.007	0.018	0.000		
11	0.175	0.075	0.007	0.005	0.010	0.022	0.010	0.009	0.032	-0.001	0.000	
12	0.178	0.076	0.007	0.005	0.011	0.023	0.011	0.011	0.043	-0.002	0.005	0.000

4. Woodstove Projected Output

Year	Q	TWV	THL	TED	WV
1984	2.60	260000	12400000	1976000	0.16
1985	2.65	273652	12368070	2100556	0.17
1986	2.70	289748	12336220	2246345	0.18
1987	2.74	303679	12304460	2377895	0.19
1988	2.78	316479	12272780	2502903	0.20
1989	2.81	328911	12241170	2627236	0.21
1990	2.84	342150	12209650	2760310	0.23
1991	2.86	354603	12178210	2889389	0.24
1992	2.88	367009	12146860	3020382	0.25
1993	2.92	384129	12115580	3192886	0.26
1994	2.94	396355	12084380	3327455	0.28
1995	2.97	409828	12053260	3474964	0.29

1. Woodstove Base Data

HIGH SCENARIO

Base Year (BASE) = 1984
Projection Term (N) = 13
Households in Base Year (HSINP) = 200000
Household Growth (HSG) = .026
BTU Requirement (BTUR) in E06 = 62
BTU Requirement Growth Rate (BTURG) = -.025
Wood Efficiency (EW) = .4
Wood Efficiency Growth (EWG) = .01
BTUs Per Cord of Wood (BTUW) in E06 = 19
Price of Wood Per Cord in 1984 (PWINP) = 30
Price of Wood Growth (PWG) = 0
Gas Efficiency (EG) = .6
Gas Efficiency Growth (EGG) = .01
Price Gas in Base Year (PGINP) Per E06 BTUs = 4.35
Price of Gas Growth (PGG) = .032
Quantity of Wood Base Year in Cords (QINP) = 2.6
Elasticity of Wood (ELW) = -.25
Elasticity of Other Fuels (ELO) = 1
Gamma Adjustment (GAMMA) = .5
Cost of Inconvenience (CI) = -.5
Pollution Impact (PI) = -.5
Woodburning Ethic (WBE) = 1
Saturation of Gas (SATG) = .66
Saturation of Electricity (SATE) = .15
Saturation of Wood (SATW) = .5
Saturation of Gas Growth Rate (SATGG) = .005
Saturation of Electricity Growth Rate (SATEG) = .018
Cost of a Woodstove (WSC) = 1000
Cost of an Electrical Furnace (ESC) = 750
Cost of a Gas Furnace (GSC) = 2500
Discount Rate in Real Terms (DR) = .06
Woodstove Projected Life (NW) = 10
Projected Life of Other Furnaces (NO) = 20
Operation, Maintenance, Repair Costs of Woodstove (OMRW) = .36
Operation, Maintenance, Repair Costs of Other Furnaces (OMRO) = .3
Depreciation of Woodstove (DW) = 1
Depreciation of Other Furnaces (DO) = 1
BTU Output Per Stove (WMAX) = 40
Saturation Conversion Rate (C) = .0003
Dummy Add On $ Per Cord (DUM) = 0
New Price of Wood (NPW) = 30
Capacity Costs of Wood (PWC) = 184.7805
Capcity Costs of Elec (PEC) = 85.00498
Capacity Costs of Gas (PGC) = 283.35

2. Woodstove Intermediate Output

Year	House Holds	Price Wood/ E06BTU	Price Gas/ E06BTU	Price Elec/ E06BTU	Price Other/ E06BTU
1984	200000	3.95	7.25	12.33	8.19
1985	205200	3.91	7.41	19.66	9.70
1986	210535	3.87	7.57	19.66	9.86
1987	216009	3.83	7.73	19.66	10.01
1988	221625	3.79	7.90	19.66	10.17
1989	227388	3.76	8.07	19.66	10.33
1990	233300	3.72	8.25	19.66	10.50
1991	239366	3.68	8.43	19.66	10.67
1992	245589	3.65	8.61	19.66	10.84
1993	251974	3.61	8.80	19.66	11.01
1994	258526	3.57	8.99	19.66	11.18
1995	265247	3.54	9.19	19.66	11.36

Year	APC	PWCA	TCW	TCO	AFCS	STRW	HSW
1984	246.62	286.41	531.15	754.45	223.30	0.50	100000.00
1985	246.23	279.25	515.51	832.64	317.13	0.55	112361.40
1986	245.84	272.27	500.34	826.72	326.38	0.57	120728.50
1987	245.45	265.46	485.63	820.84	335.22	0.59	127012.20
1988	245.06	258.83	471.36	815.01	343.65	0.60	132233.20
1989	244.66	252.35	457.53	809.23	351.70	0.60	136935.80
1990	244.26	246.05	444.11	803.48	359.37	0.61	141409.40
1991	243.85	239.89	431.09	797.78	366.69	0.61	145808.80
1992	243.44	233.90	418.47	792.12	373.65	0.61	150216.40
1993	243.03	228.05	406.23	786.50	380.28	0.61	154677.10
1994	242.62	222.35	394.35	780.93	386.58	0.62	159215.50
1995	242.20	216.79	382.83	775.39	392.56	0.62	163846.10

3. Woodstove Add On Matrix Output

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.000											
2	0.243	0.000										
3	0.364	0.024	0.000									
4	0.425	0.036	0.024	0.000								
5	0.455	0.042	0.036	0.024	0.000							
6	0.471	0.045	0.042	0.036	0.024	0.000						
7	0.478	0.046	0.045	0.042	0.036	0.024	0.000					
8	0.482	0.047	0.046	0.045	0.042	0.036	0.024	0.000				
9	0.484	0.048	0.047	0.046	0.045	0.042	0.036	0.024	0.000			
10	0.485	0.048	0.048	0.047	0.046	0.045	0.042	0.036	0.024	0.000		
11	0.485	0.048	0.048	0.048	0.047	0.046	0.045	0.042	0.036	0.024	0.000	
12	0.486	0.048	0.048	0.048	0.048	0.047	0.046	0.045	0.042	0.036	0.024	0.000

4. Woodstove Projected Output

Year	Q	TWV	THL	TED	WEV
1984	2.60	260000	12400000	1976000	0.16
1985	2.84	319429	12404340	2451934	0.20
1986	2.99	360770	12408680	2796966	0.23
1987	3.08	391826	12413030	3068113	0.25
1988	3.16	417492	12417370	3301775	0.27
1989	3.22	440568	12421720	3519113	0.28
1990	3.27	462594	12426070	3732004	0.30
1991	3.32	484409	12430420	3947077	0.32
1992	3.37	506468	12434770	4168086	0.34
1993	3.42	529022	12439120	4397237	0.35
1994	3.47	552215	12443480	4635919	0.37
1995	3.52	576134	12447830	4885089	0.39

APPENDIX F

BACKCAST TEST

APPENDIX F

BACKCAST TEST

Estimates were made for 1972 MPC parameter values to determine the suitability of the WEST simulation system in terms of prediction. The following dollar value approximations are in 1984 dollars.

Base Year (BASE) = 1973
Households in Base Year (HSINP) = 150,000
Household Growth (HSG) = .026
BTU Requirement (BTUR) in E06 = 80
BTU Requirement Growth Rate (BTURG) = -.025
Wood Efficiency (EW) = .3
Wood Efficiency Growth (EWG) = .03
BTUs Per Cord of Wood (BTUW) in E06 = 19
Price of Wood Per Cord in 1984 (PWINP) = 35
Price of Wood Growth (PWG) = 0
Gas Efficiency (EG) = .55
Gas Efficiency Growth (EGG) = .01
Price Gas in Base Year (PGINP) Per E06 BTUs = 2.1
Price of Gas Growth (PGG) = .08
Beginning Price Electricity = 16.00
Ending Price Electricity = 12.00
Quantity of Wood Base Year in Cords (QINP) = 1.9
Elasticity of Wood (ELW) = -.5
Elasticity of Other Fuels (ELO) = .5
Gamma Adjustment (GAMMA) = .25
Cost of Inconvenience (CI) = -.5
Pollution Impact (PI) = -.5
Woodburning Ethic (WE) = 1
Saturation of Gas (SATG) = .85
Saturation of Electricity (SATE) = .02
Saturation of Wood (SATW) = .4
Saturation of Gas Growth Rate (SATGG) = -.025
Saturation of Electricity Growth Rate (SATEG) = .2
Cost of a Woodstove (WSC) = 750
Cost of an Electrical Baseboard (ESC) = 750
Cost of a Gas Furnace (GSC) = 2500
Discount Rate in Real Terms (DR) = .06
Woodstove Projected Life (nw) = 10
Projected Life of Other Furnaces (no) = 20
Operation, Maintenance, Repair Costs of Woodstove (OMRW) = .36
Operation, Maintenance, Repair Costs of Other Furnaces (OMRO) = .2
Wood Cost Perception Adjustment (DW) = 1
Other Cost Perception Adjustment (DO) = 1
BTU Output Per Stove (WMAX) = 40

Saturation Conversion Rate (C) = .0003
Dummy Add On $ Per Cord (DUM) = 0
New Price of Wood (NPW) = 35
Capacity Costs of Wood (PWC) = 138.5854
Capacity Costs of Elec (PEC) = 78.46615
Capacity Costs of Gas (PGC) = 261.5538

The annual outputs resulting from the above parameters are presented in Table F-1.

The 1984 projected values are close to the 1984 estimates as well as being close to the MPC residential wood use series (Table 14). This suggests that the simulation system, with reasonable input parameter selection, is capable of producing valid projections.

TABLE F-1

BACKCAST RESULTS
(FOR MPC SERVICE AREA)

Year	Saturation Rate	Use Per Household Cords	Total Wood Use (000s)	Percent of Total Heating Requirements
1973	40%	1.9	114	5%
1974	39%	1.9	115	6%
1975	39%	2.0	121	6%
1976	39%	2.0	129	7%
1977	40%	2.1	139	7%
1978	41%	2.2	151	8%
1979	42%	2.2	165	9%
1980	43%	2.3	181	11%
1981	44%	2.4	197	12%
1982	46%	2.5	216	13%
1983	47%	2.6	235	15%
1984	48%	2.7	257	17%

Source: ECO Northwest, Ltd., Helena, Montana.

1. Woodstove Base Data

Base Year (BASE) = 1984
Projection Term (N) = 13
Households in Base Year (HSINP) = 150000
Household Growth (HSG) = .026
BTU Requirement (BTUR) in E06 = 80
BTU Requirement Growth Rate (BTURG) = -.025
Wood Efficiency (EW) = .3
Wood Efficiency Growth (EWG) = .03
BTUs Per Cord of Wood (BTUW) in E06 = 19
Price of Wood Per Cord in 1984 (PWINP) = 35
Price of Wood Growth (PWG) = 0
Gas Efficiency (EG) = .55
Gas Efficiency Growth (EGG) = .01
Price Gas in Base Year (PGINP) Per E06 BTUs = 2.1
Price of Gas Growth (PGG) = .08
Quantity of Wood Base Year in Cords (QINP) = 1.9
Elasticity of Wood (ELW) = -.5
Elasticity of Other Fuels (ELO) = .5
Gamma Adjustment (GAMMA) = .25
Cost of Inconvenience (CI) = -.5
Pollution Impact (PI) = -.5
Woodburning Ethic (WBE) = 1
Saturation of Gas (SATG) = .85
Saturation of Electricity (SATE) = .02
Saturation of Wood (SATW) = .4
Saturation of Gas Growth Rate (SATGG) = -.025
Saturation of Electricity Growth Rate (SATEG) = .2
Cost of a Woodstove (WSC) = 750
Cost of an Electrical Furnace (ESC) = 750
Cost of a Gas Furnace (GSC) = 2500
Discount Rate in Real Terms (DR) = .06
Woodstove Projected Life (NW) = 10
Projected Life of Other Furnaces (NO) = 20
Operation, Maintenance, Repair Costs of Woodstove (OMRW) = .36
Operation, Maintenance, Repair Costs of Other Furnaces (OMRO) = .2
Depreciation of Woodstove (DW) = 1
Depreciation of Other Furnaces (DO) = 1
BTU Output Per Stove (WMAX) = 40
Saturation Conversion Rate (C) = .0003
Dummy Add On $ Per Cord (DUM) = 0
New Price of Wood (NPW) = 35
Capacity Costs of Wood (PWC) = 138.5854
Capcity Costs of Elec (PEC) = 78.46615
Capacity Costs of Gas (PGC) = 261.5538

BACKCAST TEST

NOTE: beginning year is 1973
ending year is 1984

2. Woodstove Intermediate Output

Year	House Holds	Price Wood/ E06BTU	Price Gas/ E06BTU	Price Elec/ E06BTU	Price Other/ E06BTU
1984	150000	6.14	3.82	16.00	4.10
1985	153900	5.96	4.08	15.50	4.40
1986	157901	5.79	4.37	15.00	4.73
1987	162007	5.62	4.67	14.50	5.08
1988	166219	5.46	4.99	14.00	5.45
1989	170541	5.30	5.34	13.50	5.85
1990	174975	5.14	5.71	13.00	6.26
1991	179524	4.99	6.10	12.50	6.69
1992	184192	4.85	6.53	12.00	7.13
1993	188981	4.71	6.98	12.00	7.64
1994	193894	4.57	7.46	12.00	8.18
1995	198936	4.44	7.98	12.00	8.73

Year	APC	PWCA	TCW	TCO	AFCS	STRW	HSW
1984	257.34	277.17	768.40	585.20	-183.20	0.40	60000.00
1985	256.40	270.24	735.24	599.92	-135.32	0.39	59998.12
1986	255.25	263.49	703.65	615.10	-88.55	0.39	61325.40
1987	253.86	256.90	673.56	630.65	-42.91	0.39	62596.95
1988	252.18	250.48	644.89	646.42	1.53	0.40	66539.91
1989	250.15	244.21	617.57	662.25	44.68	0.41	69959.81
1990	247.71	238.11	591.53	677.87	86.35	0.42	73715.81
1991	244.81	232.16	566.70	692.98	126.28	0.43	77702.95
1992	241.37	226.35	543.03	707.18	164.14	0.44	81838.81
1993	237.33	220.69	520.46	724.19	203.72	0.46	86274.96
1994	232.62	215.18	498.94	740.62	241.68	0.47	90824.06
1995	227.20	209.80	478.41	756.08	277.67	0.48	95445.72

3. Woodstove Add On Matrix Output

	1	2	3	4	5	6	7	8	9	10	11	12
1	0.000											
2	0.025	0.000										
3	0.043	0.025	0.000									
4	0.057	0.043	0.024	0.000								
5	0.067	0.057	0.043	0.024	0.000							
6	0.075	0.067	0.057	0.043	0.024	0.000						
7	0.081	0.075	0.067	0.056	0.042	0.024	0.000					
8	0.085	0.081	0.075	0.066	0.056	0.041	0.023	0.000				
9	0.089	0.085	0.080	0.074	0.066	0.055	0.041	0.023	0.000			
10	0.091	0.088	0.085	0.080	0.073	0.065	0.054	0.040	0.024	0.000		
11	0.093	0.091	0.088	0.084	0.079	0.072	0.063	0.052	0.042	0.024	0.000	
12	0.094	0.093	0.091	0.087	0.083	0.078	0.071	0.062	0.056	0.041	0.023	0.000

4. Woodstove Projected Output

Year	Q	TWV	THL	TED	WEV
1984	1.90	114000	12000000	649800	0.05
1985	1.92	115475	12004200	677955	0.06
1986	1.97	120671	12008400	729713	0.06
1987	2.02	128751	12012610	801934	0.07
1988	2.09	139159	12016810	892763	0.07
1989	2.17	151502	12021020	1001106	0.08
1990	2.24	165484	12025230	1126300	0.09
1991	2.33	180861	12029440	1267385	0.11
1992	2.41	197412	12033650	1425434	0.12
1993	2.50	215661	12037860	1603912	0.13
1994	2.59	235133	12042070	1801193	0.15
1995	2.68	255680	12046290	2017347	0.17

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